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16. *Abstract*
Data from 59 inorganic chemical plants, as well as data obtained from the Manufacturing Chemist's Association were obtained and analyzed to determine the costs to be incurred by the industry in achieving various levels of pollution abatement by 1974. For the purposes of this study, the inorganic chemicals industry was defined as including producers of alkalies and chlorine, industrial gases, inorganic pigments, paints and allied products, fertilizers (including ammonia and urea), inorganic insecticides and herbicides, explosives, and other major inorganic chemicals. Total output was estimated at 328.7 billion lbs for 1969 and projected at 455.5 billion lbs for 1974. The historic growth rate has been 1.5 to 2.0 times that of the Gross National Product, but the overall price index of organic chemicals has fallen 2.5% in the recent past. Equalization, neutralization, sedimentation and lagooning are the most widely used treatment processes, and both capital and operation costs for waste treatment by the industry are presented for 27% and 100% removal of contaminants on a yearly basis from 1969 to 1974. Descriptions of the various production processes and the possible impact that process changes might have on the volume and character of the wastes are presented in detail. (Lowry-Texas)

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by

Datagraphics Incorporated
Pittsburgh, Pennsylvania

of an original study by

Cyrus Wm. Rice & Company
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for

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ABSTRACT

This report presents a description of the inorganic chemical industry and the costs that the industry would incur in attaining various levels of pollution abatement over the five-year period through 1974. For the study purposes, the inorganic chemical industry has been defined as including establishments producing alkalies and chlorine, industrial gases, inorganic pigments, paints and allied products, fertilizers (excluding ammonia and urea), inorganic insecticides and herbicides, explosives, and other major industrial inorganic chemicals. The report presents in considerable detail the description of the various production processes, the waste treatment methods practiced, and the possible impact that changes in processes might have on the volume and character of the wastes produced.

Projections have been based upon the chemical industry data in the 1963 and 1967 Census of Manufacturers, the 1967 Manufacturing Chemists Association survey, and the 1968 FWPCA study of the organic chemicals industry. Costs of treatment are estimated by year for the levels of treatment corresponding to 27% and 100% removal of contaminants. Data from 59 inorganic chemical plants were obtained as primary input to the study.

Key Words: Chemical wastes, treatment costs, economics, industrial effluents, survey, inorganic chemicals.

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CHAPTER I

SUMMARY

This report presents a description of the inorganic chemical industry, and the costs that the industry would incur in attaining various levels of pollution abatement over a five year period through 1974. The cost estimates have been based upon published data, general data derived from information in the files of the Contractors on industrial waste treatment methods and costs, and specific data from 59 inorganic chemical plants, some of which were supplied by the Manufacturing Chemists Association. (The data supplied by the M.C.A. were presented in such a manner as to render impossible identification of proprietary information relating to a specific plant's construction, operation, maintenance, or production.)

The inorganic chemical industry has been defined for purposes of this study as including establishments producing alkalies and chlorine, industrial gases, inorganic pigments, paints and allied products, fertilizers (excluding ammonia and urea), inorganic insecticides and herbicides, explosives, and other major industrial inorganic chemicals. The complex relationship which exists between various products and industries, however, make it extremely difficult to arbitrarily associate certain products with one category. The overall output of the industry, since its products are used for a wide variety of purposes well removed from the final consumer, depends upon the level of total economic activity rather than the economic activity in any one segment of the economy. Since new mineral sources are discovered infrequently and usually involve large development expenditures, wide fluctuations in the gap between demand and readily available supply are quite common.

Total production in the inorganic chemical industry is estimated to be 328.7 billion pounds in 1969 and projected at 455.5 billion pounds in 1974. While certain segments of the industry are growing as rapidly as 18% per year, the historical situation is for a growth rate 1.5 to 2.0 times that of the gross national product. The overall price index of inorganic chemicals, however, has fallen

2.5 percent in the recent past. Thus, expenditures for pollution control may be of greater relative significance than in other industries where prevailing rising prices can more readily absorb increased costs.

The regional growth rates reflect a continuing trend to move production facilities closer to raw materials and markets. The industry, as a whole, is thus tending to concentrate in the Midwest and Southwest.

Inorganic chemical plants vary greatly in size, level of technology, product mix, and age. The report presents in considerable detail the description of the various production processes, the waste treatment methods practiced, and the possible impact that changes in processes might have on the volume and character of the wastes produced. A typical or average plant exists, however, only in the statistical sense. The total costs given in this report are for the construction and operation of waste treatment facilities for the industry as a whole and cannot be used to determine costs for individual plants. The costs given are for the waste treatment facilities only. The costs entailed in process changes, restriction of plant operations, sewer segregation, particularly in older plants, are not included. Treatment system construction and operating costs for a particular plant can only be estimated by detailed engineering studies.

Projections based upon the chemical industry data in the 1963 Census of Manufactures, the 1967 Manufacturing Chemists Association survey, the 1968 FWPCA study of the organic chemicals industry, and the costs of treatment for the two levels of 27% and 100% removal of contaminants show the following projected operating costs and cumulative capital investment for wastewater treatment.

PROJECTED CUMULATIVE INORGANIC CHEMICAL INDUSTRY CAPITAL COSTS FOR WASTE TREATMENT, 1969-74

%	Costs in Millions of Current Dollars [1/]					
Removal	1969	1970	1971	1972	1973	1974
27	314.3	341.7	377.9	420.1	467.7	519.4
100	1898.8	2062.2	2281.9	2537.1	2823.5	3118.5

PROJECTED INORGANIC CHEMICAL INDUSTRY ANNUAL OPERATING COSTS FOR WASTE TREATMENT, 1969-74

%	Costs in Millions of Current Dollars 1/					
Removal	1969	1970	1971	1972	1973	1974
27	86.1	93.6	103.5	115.1	128.1	142.3
100	165.4	179.6	198.7	221.0	245.9	273.2

1/ Based on an average 3.6% annual increase in the price level

Contaminated wastewater from the inorganic chemical industry comes primarily from electrolysis and crystallization brines, washings from filter cakes, spent acid and alkalies, and washings from raw materials. These wastewaters are generally characterized by dissolved solids and suspended solids. In addition to contaminated waste streams, process cooling discharges occur, accounting for 40 to 80% of the total discharge on the average. Treatment practices vary but involve in-plant segregation of contaminated wastes from uncontaminated cooling waters.

Many waste treatment methods are available depending on the degree of treatment required, however, equalization, neutralization, sedimentation and lagooning processes are most widely used. Biological treatment is not applicable since the contaminants are primarily dissolved or suspended inorganic materials. Plants with small discharges tend to employ only equalization and neutralization with total discharge to municipal sewer systems for joint treatment. It is estimated that between 10 and 20% of the process wastewater discharge from the industry is to municipal systems (7.9% of the total discharge). No significant percentage changes in this regard are expected through 1974. The inorganic chemical industry has generally found that in-plant, separate treatment has economic advantages, particularly when significant quantities of wastewater are involved.

Data from 59 inorganic chemical plants were obtained and formatted according to the Industrial Waste Treatment Practices Data Form, which was developed for the study "The Cost of Clean Water and Its Economic Impact, Volume IV," United States Department of the Interior, January,

1969. The data obtained are given in some detail in the report in terms of bar graphs and various calculated parameters relating wastewater volumes, plant production, and costs.

Key parameters of interest regarding waste treatment costs are the following:

Average capital cost	$223/1000 gpd
Average operating cost/yr.	$58.49/1000 gpd
Average wastewater flow	16.73 gpd/annual ton of production
Average capital cost	$3.74/annual ton of production
Average operating cost	$0.98 per year/annual ton of production

An examination of the survey data showed that the reported bases of waste treatment decisions were generally least cost, or minimum compliance with pollution control regulations.

The costs of unit wastewater treatment methods were developed and are presented in the report as a series of mathematical models and cost function graphs. These data were used to calculate capital costs of waste treatment facilities versus two levels of pollutant removal for a series of typical plants. Treatment Level I was chosen to represent the average treatment employed in the industry as a whole and is judged to be equivalent to 27% removal of suspended and dissolved solids. Treatment Level II represents complete removal of contaminants. Only two levels were selected because the industrial wastes are principally inorganic solids that respond only to physical treatment processes. Because there are no intervening technologies, intermediate levels of efficiency are not distinguishable. The two levels then may be viewed as a range bounded on the one side by the current level of efficiency and on the other by universal application of advanced treatment practices. An almost infinite number of intermediate positions are possible for the industry as a whole within the range, but only as the treatment II technology is applied to individual units of the population. Unlike the case of organic waste, there is no series of technological plateaus through which the whole population may progress.

The following table summarizes the capital and operating costs in 1969 dollars for the two levels of treatment chosen:

% Removal Contaminants	Capital Cost $/1000 gpd	Operating Cost ¢/1000 gal
27 (SS and Acidity)	300	26.0
100 (TDS)	2185	51.5

CHAPTER II

INTRODUCTION

This study was performed pursuant to Contract No. 14-12-592 with the Federal Water Pollution Control Administration, United States Department of the Interior.

The primary objective of this study was to acquire data and develop cost estimates on the waste treatment practices of selected industrial categories within the inorganic chemicals industry over the 1970 to 1974 period. A secondary objective of the study was to further test and refine as necessary the generalized methodology for establishing and projecting industry costs which was developed in the course of work under FWPCA Contract No. 14-12-435 "Projected Wastewater Treatment Costs in the Organic Chemicals Industry." This report was transmitted to the Congress in January, 1969 as The Cost of Clean Water, Volume IV.

The information contained in this report is not intended to reflect the cost or waste load situations for any particular plant. A generalized framework for analyzing waste treatment practices has been provided instead. The data and conclusions should be useful to industry and to government in their efforts to find and implement the most efficient ways to reduce pollution of the nation's water bodies.

The study utilized on subcontract the services of Resource Engineering Associates, Inc., Stamford, Conn., Datagraphics, Inc, Allison Park, Pa., and Gurnham, Bramer, and Associates, Inc., McMurray, Pa. Assistance from the Manufacturing Chemists Association in supplying data, comments, and suggestions is gratefully acknowledged.

CHAPTER III

THE INORGANIC CHEMICAL INDUSTRY

The inorganic chemical industry is not easily definable in terms of the Standard Industrial Classification (SIC) numbers. However, for the purpose of this study, it was necessary to define the industry as follows:

2812 - Alkalies and chlorine
2813 - Industrial gases (except for organic gases)
2816 - Inorganic pigments
2819 - Industrial inorganic chemicals, n.e.c.
2851 - Paints and allied products
2871 - Fertilizers (not including ammonia and urea)
2879 - Inorganic insecticides and herbicides
2892 - Explosives

The most important of the groups in terms of product value may be noted as 2819, 2812, and 2871. However, it is not sufficient to ignore such groups as 2813 which includes the important production of nitrogen and oxygen, 2851 which includes the vital surface coatings industry, or 2816 which involves inorganic pigments such as titanium oxide. The surface coatings industry is typical of the relationship which exists between segments of the inorganic industry and the organic chemical industry. The solvents and film formers which are utilized within the inorganic chemical industry for the production of surface coatings are important products of the organic chemical industry while inorganic pigments, primarily oxides and salts of titanium, iron and other metals are products which fall into the inorganic industry category. We have defined the total product as being part of the inorganic industry. However, it is obvious that the complex relationships which exist between various products and industries (necessary to the smooth functioning of our technological state) make it extremely difficult, if not impossible, to arbitrarily associate certain products with one SIC category. Product profiles are given in Appendix C, along with typical product process flow sheets.

The overall output of industrial inorganic chemicals, since they are utilized in a wide range of industries and for a wide variety of purposes usually well removed from the final consumer, depends upon the level of total economic activity rather than economic activity in any specific segment of the economy.

Changes in consumer preferences or redistribution of income and spending, such as changes in tax levels or defense spending, may affect product mixes, but do not significantly affect total industry output. In general, price competition and product substitution are not as significant in the inorganic chemical industry as in the organic chemical sector. However, changes although slow to come tend to be quite profound.

Supplies of raw materials frequently vary and, in the case of certain materials, the industry may face serious shortages until new raw material sources (usually ores or brines) are developed. The widely fluctuating price of sulfur over the past ten years is a classic case resulting from supply fluctuations which can be matched by mercury, potash and silver, among others. Since new sources of minerals are found infrequently and usually involve relatively large expenditures to develop, wide fluctuations in the gap between demand and readily available supply are quite common in the inorganic chemical industry.

Industrial chemical industries are generally capital intensive operations (with a few exceptions such as the paint manufacturing industry), and are characterized by high productivity ($75,000 annual output per production worker), high wages, a low labor turnover, and a continuing demand for skilled labor. Most of the plants operate continuous and must operate at 75 to 85 percent of capacity to maintain adequate levels of efficiency and profitability. Smaller plants generally operate batch processes and, hence, tend to produce low volume, high cost, specialized chemicals. Financial ratios for the chemical and allied products industry are shown in Table I.

TABLE I

FINANCIAL RATIOS FOR THE CHEMICALS AND ALLIED PRODUCTS INDUSTRY

Ratio	1963	1965	1967	1968	1969 1/
Profits after taxes/sales (%)	7.5	7.9	6.9	6.8	6.8
Profits after taxes/net worth (%)	12.9	14.7	12.6	13.1	13.3
Capital expenditure/gross plant (%)	6.3	8.2	7.6	-	-
Depreciation/gross plant (%)	6.1	5.8	5.8	6.0	5.9
Depreciation/sales (%)	4.5	4.4	4.5	4.5	4.3
Sales/total assets	1.13	1.13	1.10	1.14	1.15

1/ First half

SOURCE: U.S. Industrial Outlook, 1970, U.S. Department of Commerce

Profits after taxes as a percentage of sales in the inorganic chemical industry ranged from 6.5 in 1967 to 7.9 in 1964-65. By comparison, comparable profits for all manufacturing industries were 5.0 in 1967 and 5.4 in 1968. It is important to note that while the inorganic segment attracts less attention than the organic sector, satisfactory profits are generally associated with investment in this segment.

The estimated value of inorganic chemical shipments for 1969 and 1970 are shown in II.

TABLE II

VALUE OF ESTIMATED INORGANIC CHEMICAL SHIPMENTS
(1969-70) ($ million)

SIC	1969	1970
2812	792	832
2813	653	715
2816	690	725
2819	4305	4500
2851	3459	3675
2871-72	1856	1904
2879	830	880
2892	517	533

SOURCE: U.S. Industrial Outlook, 1970, U.S. Department of Commerce

Further comparisons within the inorganic chemical industry show that the price index for the chemical industry in mid-1969 was 96.7 on the basis of 1957-59 = 100. In 1968, the level was 98.8. The paint industry price index was 114.4 in 1968 and 118.7 in 1969. The fertilizer industry price level was 102.3 in 1968 and 88.8 in 1969. Several factors distinguish the inorganic chemical industry and its relationship to waste management. Among these are the following:

1. While certain segments of the industry are growing rapidly, the more common situation is for a growth rate at 1.5 to 2 times that of the gross national product and several of the major chemicals have growth curves which might be substituted for a

historical projection of industrial growth in general. This strong growth will affect the need for pollution control facilities.

2. Capital investment is generally considerable and, because of the nature of inorganic chemistry and its long history of relatively unchanging practice, rapid technological obsolescence does not occur. Consequently, new capacity is not quickly built. This industry moves more slowly to increase plant capacity than the organic chemical industry for example. Accordingly, the inorganic chemical industry with its relatively aged plant in place faces relatively high expenditures for added pollution control facilities.

3. The overall price index of chemicals, in contrast with the general experience of American industry, has fallen two to five percent in the recent past. Thus, expenditures for pollution control may be of greater relative significance than in other industries where prevailing rising prices can more readily absorb increased costs.

4. Inorganic chemical plants tend to be located to take advantage of such business factors as the availability of raw materials, low cost power, or markets. Considerations relating pollution control and plant location have been of minor importance in the past.

5. Many facilities are old and completely depreciated. Accordingly, there is little incentive to build pollution control facilities to handle wastes from an obsolete operation. Because of the nature of the industry, obsolete units remain sufficiently profitable to continue in use.

6. Characteristically, inorganic chemicals are handled in only two or three steps from raw material (brine or ore, usually) to product for use by industry elsewhere. While the inorganic chemical industry includes a large number of products and processes with the possibility of many different products at a particular production site, there are a limited number of products which comprise the bulk of the

value of this industry's production; these are discussed in detail in Appendix C to this report along with the wastes generated by their production. The location of this portion of the industry's production is shown on Map A.

LOCATION OF MAJOR INORGANIC CHEMICAL PLANTS
SIC NOS. 2812, 2816, 2819

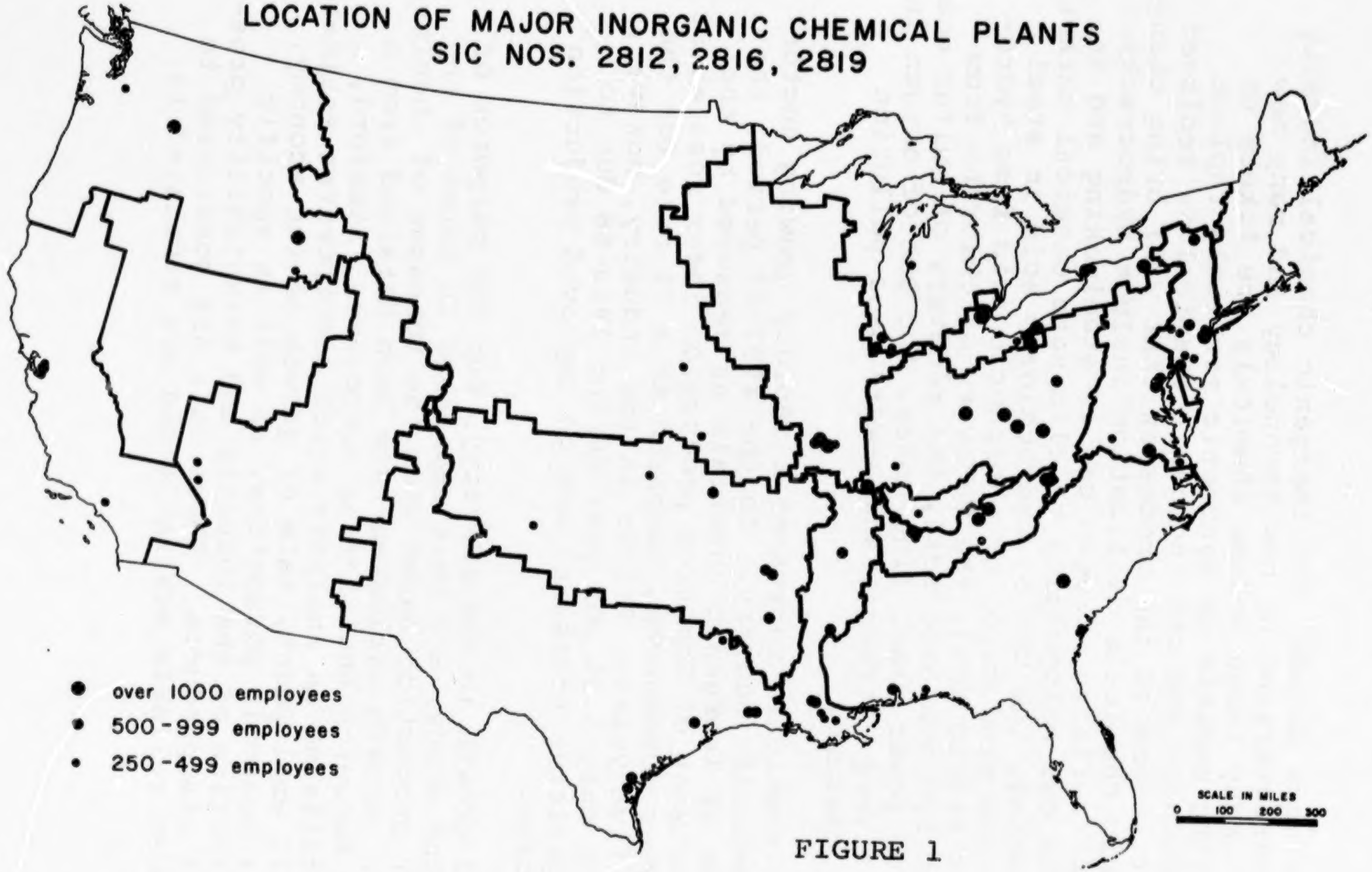

● over 1000 employees
● 500 - 999 employees
• 250 - 499 employees
SCALE IN MILES
0
100
200
300

FIGURE 1

This map represents a compilation, in content and configuration, of the location of major inorganic chemical plants classified by SIC 2812, 2816, and 2819. The source of this information was the book by Barry R. Lawson, ***Atlas of Industrial Water Use – A Report to the Water Resources Council,*** Cornell University Water Resources Center, Ithaca, New York, Publication No. 18, September, 1967, pp. 21, 25 & 29.

CHAPTER IV

PROJECTED INDUSTRY GROWTH

During the next decade, the inorganic chemical industry will be characterized by new technology and many new products. Many large volume chemicals are likely to face changing markets as synthetic materials replace natural products and one inorganic chemical is replaced by another. Some of the processes that will bring changes in inorganic chemicals utilization include hydrocracking in gasoline refining, oxygen use in steelmaking and in blast furnaces, holopulping to eliminate chemical markets in papermaking, the use of hydrochloric acid in steel pickling, the production of phosphoric acid from hydrochloric or nitric acid, the recovery of chlorine from by-product hydrochloric acid, the recovery of sulfur compounds from power plant flue gases, the use of oxygen in sparging rivers, streams, and sewers as a pollution abatement measure.

Inorganic chemicals represent a rapidly growing sector of the chemical industry. In the 1963-69 period, the production of inorganic chemicals as measured by the U.S. Department of Commerce production index rose about 12% per year compounded, compared to a 7% rate for the previous five years. Prices in the industry, however, have risen only 5.3% per year during 1963-68 due to both competitive pressures and to improved production efficiencies.

Projected growth in the industry, for the purposes of the present study, are best expressed in terms of the volume of production based upon the tonnages of chemicals produced. Growth estimates have been obtained from a study by Resource Engineering Associates, Stamford, Conn., utilizing an analysis which incorporates estimates of overall employment, rate of growth of the economy, and other economic parameters, as well as specific characteristics of the industry and marketability prospects for its products. These data are considered to be the most reliable available and are tabulated in Table I.

TABLE I

PRODUCTION OF INORGANIC CHEMICALS
(millions of tons unless otherwise noted)

SIC	1968	1969	1970	1971	1972	1973	1974
2812	24	25	26	28	30	32	34
2813 1/	365	420	495	595	715	850	1000
2816	1.20	1.25	1.29	1.37	1.44	1.51	1.59
2819	70	72	74	77	80	84	88
2851 3/	843	899	944	1000	1060	1124	1191
2871	41.50	41.80	42.25	43.94	46.14	47.99	49.91
2879	0.20	0.20	0.19	0.18	0.18	0.17	0.15
2892 2/	250	264	274	282	293	305	322

1/ High purity oxygen and nitrogen only (billions of cu. ft.)
2/ Millions of dollars
3/ Millions of gallons

The above data are applicable to the inorganic chemical industry as a whole, but rates of growth vary in the various segments of the industry and from one geographical region to another. Expected rates of growth over the next decade according to industry segment and according to geographical region are given in Tables II and III.

TABLE II

INDUSTRY SEGMENTAL GROWTH RATES THROUGH 1979

SIC No.	Growth Rate (%/year)
2812	6
2813	18
2816	5
2819	4
2851	6
2871	4
2879	1
2892	4

SOURCE: REA Projections

The above growth rates are based upon volumes of production and assume a real growth in the Gross National Product of 3.5% per year.

TABLE III

INDUSTRY GROWTH RATES GEOGRAPHICALLY THROUGH 1975

Region	Growth Rate (%/year)
Northeast and Middle Atlantic	4
Southeast	6
Gulf Coast	5
North Central	10
Mid South	10
Mountain States	4
Pacific Coast	5

SOURCE: REA Projections

The regional growth rates reflect the continuing trend to move production facilities closer to raw materials and markets. The industry will thus tend to concentrate more heavily in the Midwest and Southeast.

CHAPTER V

WASTEWATER CHARACTERISTICS

Wastewater from inorganic chemical processing consists both of contaminated and relatively clean effluent streams. In general, the contaminated wastewaters are those taken from processes while the cleaner wastewaters are those used for indirect heat exchange, general washing, etc.

Contaminated Wastewaters

The major sources of contaminated wastewaters are as follows:

1. Brines arising from electrolysis and crystallization
2. Filter cake washings
3. Waste acid and alkaline streams
4. Washing streams containing substantial amounts of suspended particulate matter

These waters are generally characterized by dissolved solids and suspended solids. Typical sources are discussed in connection with the various processes described in detail in Appendix C of this report.

Clean Wastewaters

Clean waters, which are basically uncontaminated and can be discharged untreated, are not included in the total flows given in wastewater totals. Cooling water and steam condensates are the primary sources of such water, and a typical breakdown is given in Table I.

Also included is an indication of potential pollutants and associated sources and concentrations. Because these clean wastewaters are relatively uncontaminated and exert little pollutional effect (except thermal) on the environment, care must be exercised to prevent their contamination.

The thermal effects cannot be ignored. Effluent heat loads can adversely affect the surface receiving waters, causing decreased oxygen solubility and greater oxygen utilization. Both of these effects significantly

TABLE I

COMPOSITION OF TYPICAL CLEAN WATER EFFLUENT

Water Sources	% of Total Wastewater	Flow Range (gpm)	Potential Pollutant Sources
Cooling Water (excluding sea water)	40 - 80	100 - 10,000 (500 - 200,000 (gal. water ton product)	Process leaks: Bearings, exchangers etc.
Steam Equipment	10	50 - 1,000	Water treatment Scrubbed from air through tower Make-up water Boiler blowdown Waste condensate

reduce the ability of the receiving water to assimilate waste loads. Through the use of cooling towers, the quantity of high temperature wastewaters discharged has been greatly reduced.

The segregation of clean wastewater flows is widely practiced throughout the inorganic chemical industry, as a result of overall wastewater treatment economics and regulatory requirements. Although there is a limited possibility that wastewater flows can be further reduced by segregating additional clean waters, most major clean waters are currently collected and either recirculated or discharged separately in those inorganic chemical plants with treatment facilities.

Thermal Pollutants

Many process facilities in the inorganic chemical industry generate large amounts of thermal energy which must be removed by the circulation of cooling waters or air. Additional heat is released through the release of hot brines from evaporators, etc. Of particular significance are the gas producing plants because of their need to discharge the thermal energy extracted from air or natural gas during their compression and cooling to sub-zero temperatures. In many cases, the problems of thermal pollution are reduced through the use of cooling towers. In the latter case, the blowdown from such recirculating systems may contain substantial amounts of chemicals added to the cooling water such as chromates, zinc, phosphates, bactericides, organics, etc., which may constitute a pollution problem.

In the case of many industries, there is concerted effort to produce by-product steam from excess thermal energy. In the manufacture of sulfuric acid, for example, by-product steam is important to process economics. In many other cases, however, waste hot brines and other similar waste flows are held in ponds for cooling prior to discharge into surface waters.

CHAPTER VI

WASTEWATER TREATMENT METHODS

A variety of sequences of wastewater treatment are available for wastes from inorganic chemical manufacture. Their use depends on the nature of the waste and treatment requirements. These sequences are indicated in Figure 1. Three typical cases will be presented. These are:

I. Waste-containing dissolved and suspended solids
II. An excess thermal energy discharge
III. Waste-containing dissolved solids

Treatment Sequence I

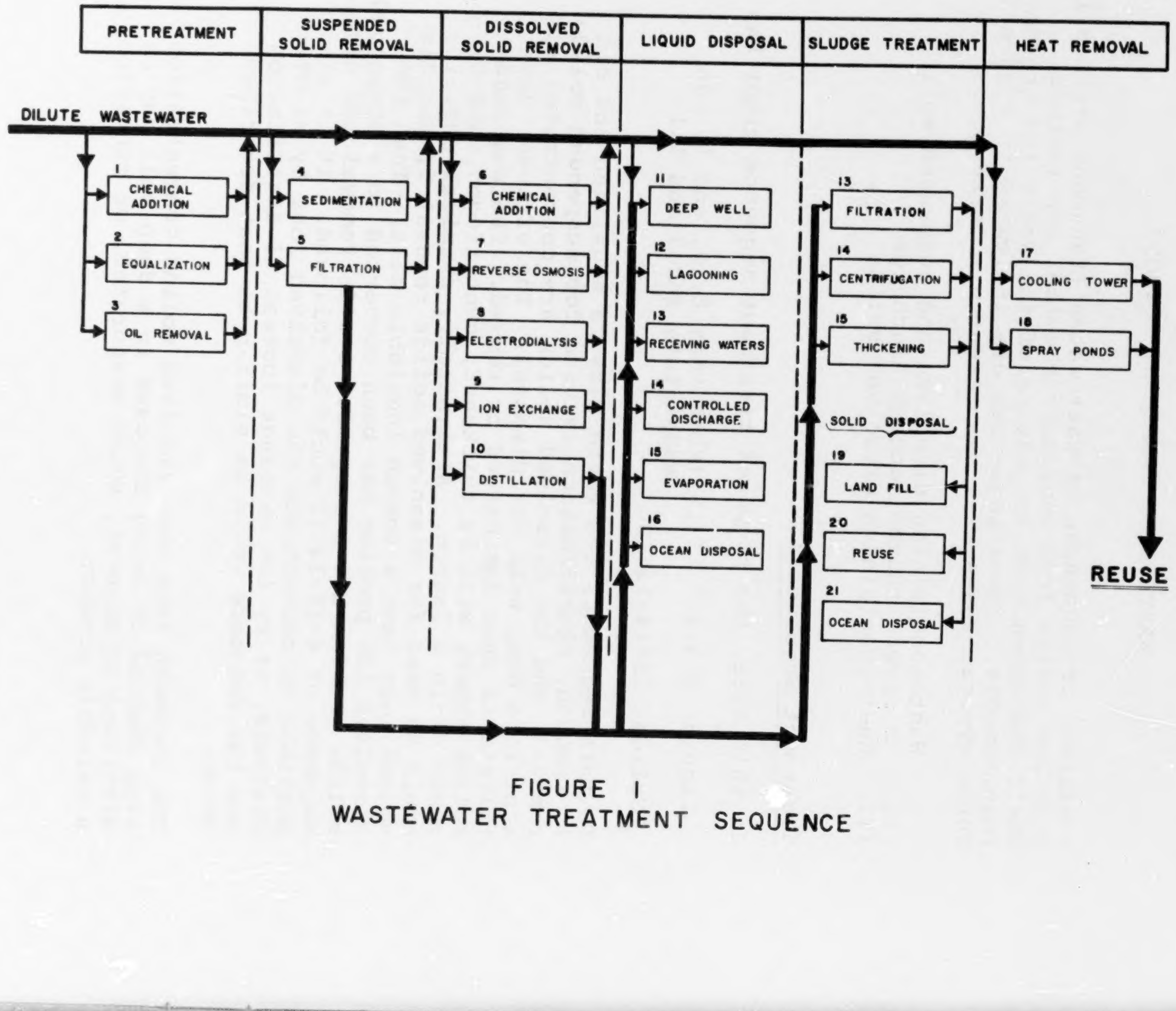
In this case, the proposed treatment sequence might be:

Liquid 2-3-4-7-11-15 (Note that 8, 9, and 10 can substitute for 7 and 11)

Solids 15-14-12-19

In this sequence, the waste flow is equalized and oil is removed, clarification is used for suspended solids removal, and the dissolved solids are concentrated and sent to a deep well for disposal. The effluent distillate is then discharged or reused. The suspended solids slurry will be thickened, centrifuged, and disposed of in a lagoon. Alternately, chemical addition could be used for dissolved solids removal if the dissolved ions have a common insoluble salt. Then the dissolved ion problem has been converted to a suspended solids problem and a suspended solids removal and disposal sequence of 4-15-14-12 would be followed. It is also possible to concentrate the dissolved ions by electrodialysis, or by ion exchange instead of distillation and the sequence would be similar to that described above.

The blowdown from the dissolved solids concentration step instead of being disposed in a deep well may be distilled to dryness, solar evaporated, or converted to a saleable product.



PRETREATMENT
SUSPENDED SOLID REMOVAL
DISSOLVED SOLID REMOVAL
LIQUID DISPOSAL
SLUDGE TREATMENT
HEAT REMOVAL
DILUTE WASTEWATER
1 CHEMICAL ADDITION
2 EQUALIZATION
3 OIL REMOVAL
4 SEDIMENTATION
5 FILTRATION
6 CHEMICAL ADDITION
7 REVERSE OSMOSIS
8 ELECTRODIALYSIS
9 ION EXCHANGE
10 DISTILLATION
11 DEEP WELL
12 LAGOONING
13 RECEIVING WATERS
14 CONTROLLED DISCHARGE
15 EVAPORATION
16 OCEAN DISPOSAL
13 FILTRATION
14 CENTRIFUGATION
15 THICKENING
SOLID DISPOSAL
19 LAND FILL
20 REUSE
21 OCEAN DISPOSAL
17 COOLING TOWER
18 SPRAY PONDS
REUSE

FIGURE I
WASTEWATER TREATMENT SEQUENCE

Treatment Sequence II

Here the proposed treatment sequence would be:

17-6-4-13

That is, a cooling tower (or a spray pond) would be installed and the cooled effluent discharged or recycled. If recycling is used, then the blowdown from the system may be treated by chemical addition and clarification to remove undesirable components (especially hexavalent chrome and zinc added for corrosion control) prior to discharge. The suspended matter would then go into a suspended solids disposal sequence discussed above.

Treatment Sequence III

With a very light suspended solids load but a heavy dissolved solids load, the sequence (with excess acidity) would be:

2-1-7-11-13

where neutralizing would be prescribed following equalization. This would be followed by reverse osmosis (or distillation, electrodialysis, ion exchange or chemical addition depending upon the circumstances) and discharge. The concentrate would be disposed of in a deep well or evaporated to dryness.

At this point, it is important to note the existence of two significant treatment sequences of general importance. They are:

	Treatment Sequence
a) excessive acidity or alkalinity streams	1
b) many high dissolved solids streams	2-5-11

The above two treatment sequences are commonly used in many circumstances in this industry. These treatment sequences, of course, do not represent all those used by the industry but are considered to be the most prevalent.

Joint Industrial Municipal Treatment

According to the U.S. Department of Commerce's 1968 publication, Water Use in Industry, (the most recent available report), a total of 1.251 trillion gallons of water (excluding SIC 2879 Inorganic Insecticides and Herbicides) were discharged from plants of this industry group. Of this total, some 98.4 billion gallons, or 7.9%, were discharged to municipal systems. These studies, which are supported by others, indicate that there is tremendous variation within groups. The study (see Table I) indicates that the SIC groups 2812, 2819, 2871, and 2892 do not make significant use of municipal systems, undoubtedly because of the nature of their discharges (high chlorides, conservative species, low or high pH) and their volume as well as the location of the plants. SIC 2813 and 2851 make extensive use of municipal systems. The data for 2813 were not available, but because of the plant locations and the fact that the waters discharged are primarily cooling waters, it is estimated that 40 percent goes into municipal systems. The data on SIC 2879 are inconclusive and that on 2816 indicate that a significant though not necessarily major percentage of the plants do use municipal facilities.

The data in Table I apply only to plants reporting water use of at least 20 million gallons per year or having more than 100 employees. The distribution of water use by SIC categories and plant sizes is shown in Table II for 1963, the latest available data. The distribution of employees is shown in Table III.

TABLE I

WATER DISCHARGE BY SIC (1)

Inorganic Industry	SIC	Total Discharge (billion gals/yr)	Discharge to Municipal Systems (billion gals/yr)	Percent to Municipal Sewers
Alkalies	2812	364.1	47.2	13.0
Gases	2813	80.8	2.7	3.3
Pigments	2816	91.5	1.0	1.1
Chemicals	2819	468.0	42.6	9.1
Paints	2851	6.5	4.6	70.8
Fertilizers	2871	97.4	0.3	0.3
Herbicides	2879	Not available	Not available	-
Explosives	2892	143.1	Less than 50 million gallons	0.0

(1) U.S. Census Bureau, Census of Manufactures (1968), Water Use in Manufacturing

TABLE II

EMPLOYMENT DISTRIBUTION (1)

Number of Employees	SIC 2812	2813	2816	2819	2851	2871	2879	2892
1-4	3	130	14	168	468	8	106	31
5-9	1	86	13	85	242	7	62	5
10-19	-	115	11	107	311	14	61	4
20-49	5	110	22	117	350	55	66	13
50-99	5	33	11	92	171	71	23	7
100-249	12	12	12	74	113	40	19	15
250-499	6	1	11	42	36	14	4	5
500-999	6	-	1	21	8	3	2	6
1,000-2,499	6	-	3	8	2	1	1	1
2,500 and more	-	-	-	4	-	-	-	5

(1) U.S. Census Bureau, ibid

TABLE III

DISTRIBUTION OF WATER USE - 1963

Number of Establishments Reporting Indicated Water Use (mil. gal/yr)	SIC 2812	SIC 2813	SIC 2816	SIC 2819	SIC 2851	SIC 2871	SIC 2879	SIC 2892
Less than 1	4	197	32	189	981	104	218	28
1-9	2	106	13	98	162	50	23	4
10-19	1	36	4	39	28	24	2	5
20-99	2	33	7	60	38	32	7	4
100+	29	49	20	138	15	31	3	17

U.S. Census Bureau, 1963 Census of Manufacturers, Water Use in Manufacturing

The smallest plants tend to discharge effluent to municipal sewers but they also tend to discharge small volumes of water. If we assume that they discharge all of their effluent water to municipal sewers, the figures change as shown below:

SIC	Percent to Municipal Sewers From Table I	Percent to Municipal Sewers Recalculated
2812	13.0	13.0
2813	3.3	4.9
2816	1.1	1.3
2819	9.1	9.3
2851	70.8	100.0
2871	0.3	1.0
2892	0.0	Not available

Thus, the total discharge on a percentage basis is not significantly changed and would approximate 8.2 percent of the total.

It is significant to note that the total percentage, and that within an SIC group, is not going to increase significantly in the future. Spreading municipal systems and increasing pressure on industry to treat its wastes will be counter-balanced by restrictions on discharges into municipal systems which will be especially true with regard to discharges from the inorganic chemical industry. It is likely that waste streams currently being discharged into municipal systems from this industry's establishments will be reduced because of increasingly stringent sewer restrictions. The main point is that there is not much point in co-treating a highly conservative, dissolved solids waste stream in a facility designed to treat non-conservative, suspended and colloidal solids wastewaters.

Sewer restrictions which may bar or establish limitations on chlorides, total dissolved solids, suspended solids, heavy metals, color, pH, etc., are the principal barriers to the acceptance of wastewaters from this industry into a municipal system. Economics rarely play a role since almost any charge levied by a municipality would be cheaper than known techniques for treating inorganic dissolved solids in most locations where direct discharge to receiving streams is not permitted.

Rates vary from the infrequent zero cost to a rate on a par with residential customers up through above average costs based on surcharges or intentional industrial burdens. Charges may run from $0.10-$1.00/1000 gallons with a level of \$0.30-\$0.40/1000 gallons at the 30-50 mgd treatment level believed to be average.

The chemical industry has generally found that in-plant, separate treatment for neutralization and suspended solids removal has economic advantages, particularly when significant quantities of contaminated wastewaters are involved. No significant percentage increase in the amount of wastewaters treated in municipal systems is expected in the near future. If complete, water renovation of municipal wastewater becomes common, however, then joint treatment for this industry's wastewater might become more common and desirable.

CHAPTER VII

INDUSTRIAL WASTE TREATMENT PRACTICES DATA FORM

The Industrial Waste Treatment Practices Data Form was developed as a part of the study entitled "Projected Wastewater Costs in the Organic Chemicals Industry" under Federal Water Pollution Control Administration Contract No. 14-12-435 and published as a part of "The Cost of Clean Water and Its Economic Impact - Volume IV," United States Department of the Interior, January, 1969, and further refined in a subsequent study entitled "Inorganic Chemicals Industry Profile" under Federal Water Pollution Control Administration Contract No. 14-12-592 and published as a part of "The Economics of Clean Water - Volume Three," United States Department of the Interior, March, 1970.

CHAPTER VIII

PLANT SURVEY DATA

The Industrial Waste Treatment Practices Data Form was used to tabulate data from 59 inorganic chemical plants. The basic data obtained are tabulated in Appendix B and are portrayed in the bar graphs of Figures 1 to 9.

From those plants for which adequate information was available, the following average statistics were calculated:

Average production = 280,734 tons per year
Water use per plant = 27,034,619 gpd
Wastewater discharge per plant = 4.697 mgd
Average treatment efficiency = 85%
Average capital costs of treatment facilities = $1,048,578
Average operating costs of treatment facilities = $274,730 per year

Generalizing the above data:

Average capital cost = $223/1000 gpd
Average operating cost = $58.49 per year/1000 gpd
Average wastewater flow = 16.73 gpd/annual ton of production
Average capital cost = $3.74/annual ton of production
Average operating cost = $0.98 per year/annual ton of production

The generally fragmentary nature of the survey data is indicative of the status of wastewater treatment in this segment of the chemical industry. Wastewater treatment practices tend to be those which reduce gross pollutants such as acidity, oil, and suspended solids. The refractory nature of the wastes from most of the industry's processes would require more advanced treatment technologies than have generally been applied.

The production, capital costs, and operating costs data reported per plant are judged to be reliable. Such data are easily obtained from plant records. The data reported on wastewater flows, however, are not sufficiently reliable to be used for projection calculations; these data are in error in that contaminated wastewater flows are not accurately differentiated from cooling water effluents.

Even though an extensive correlation study was made, no statistically significant relationships were found among the various cost-related parameters. The relationship indicated in Figure 10 showing operating costs of treatment facilities per ton of annual production as a function of capital costs of facilities per ton of annual production is the most useful found; it can be used to indicate at least order-of-magnitude variations.

Among the plants in the survey sample, production capacities were generally low while wastewater volumes reported tended to be high. Most of the plants employed more than 100 persons and were less than 10 years old. The plants were widespread geographically and, accordingly, may be considered to be representative in this regard. The bases of treatment decisions for these plants were generally least cost or minimum compliance with regulations. A few decisions were made on the basis of a projected economic return and only one plant decision was based on ultimate treatment.

FIGURE 1

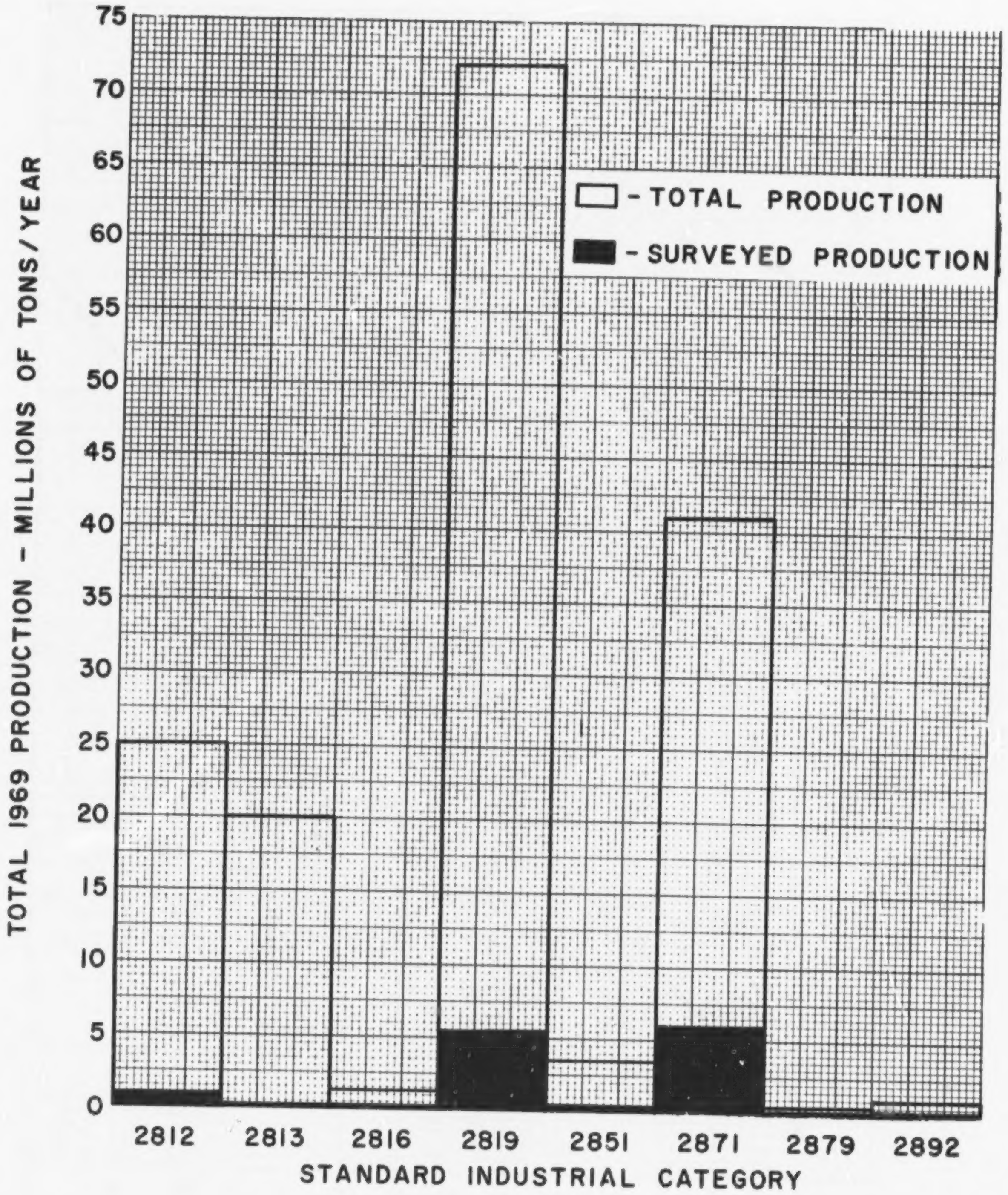

75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
TOTAL 1969 PRODUCTION - MILLIONS OF TONS/YEAR
☐ - TOTAL PRODUCTION
■ - SURVEYED PRODUCTION
2812
2813
2816
2819
2851
2871
2879
2892
STANDARD INDUSTRIAL CATEGORY

FIGURE 2

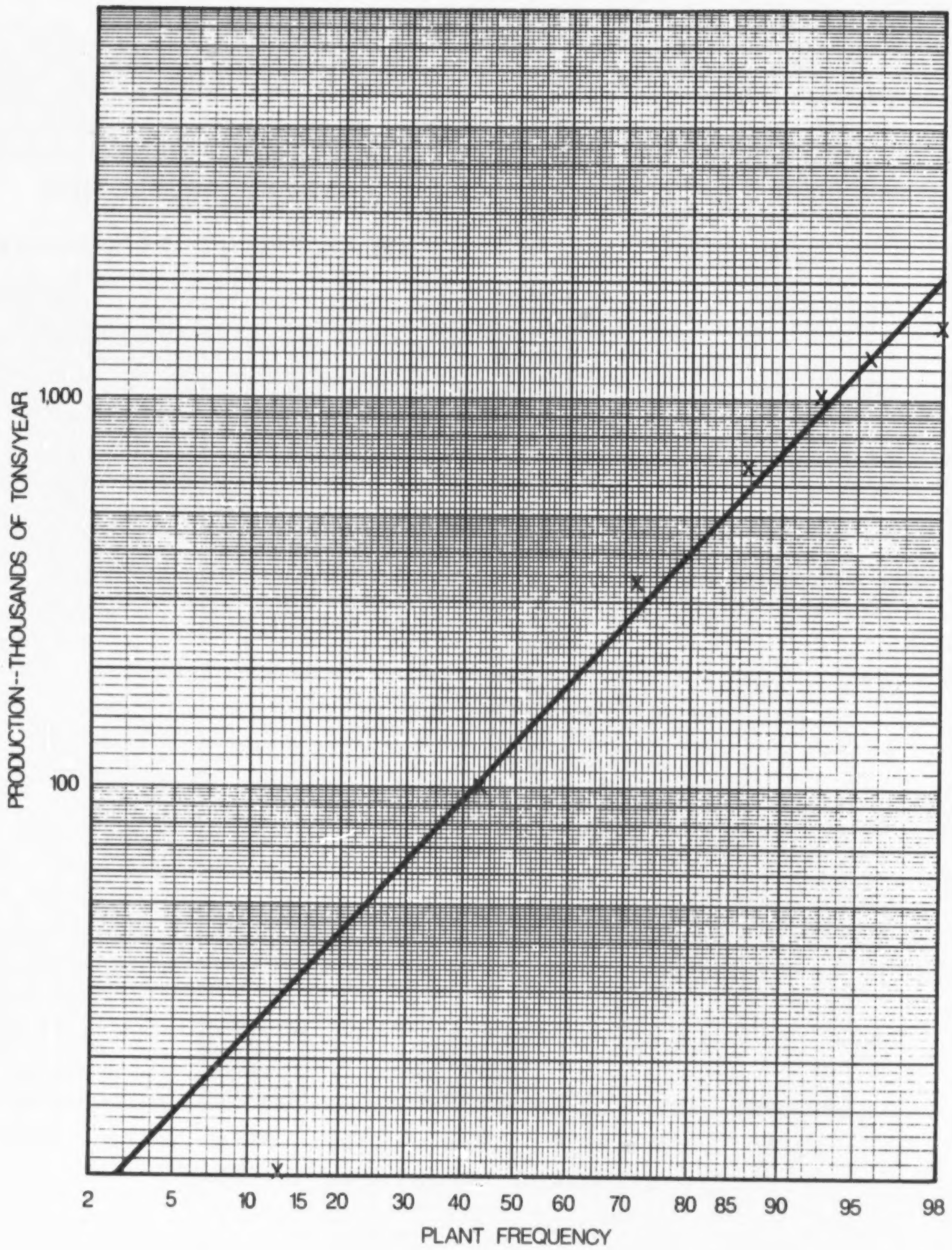
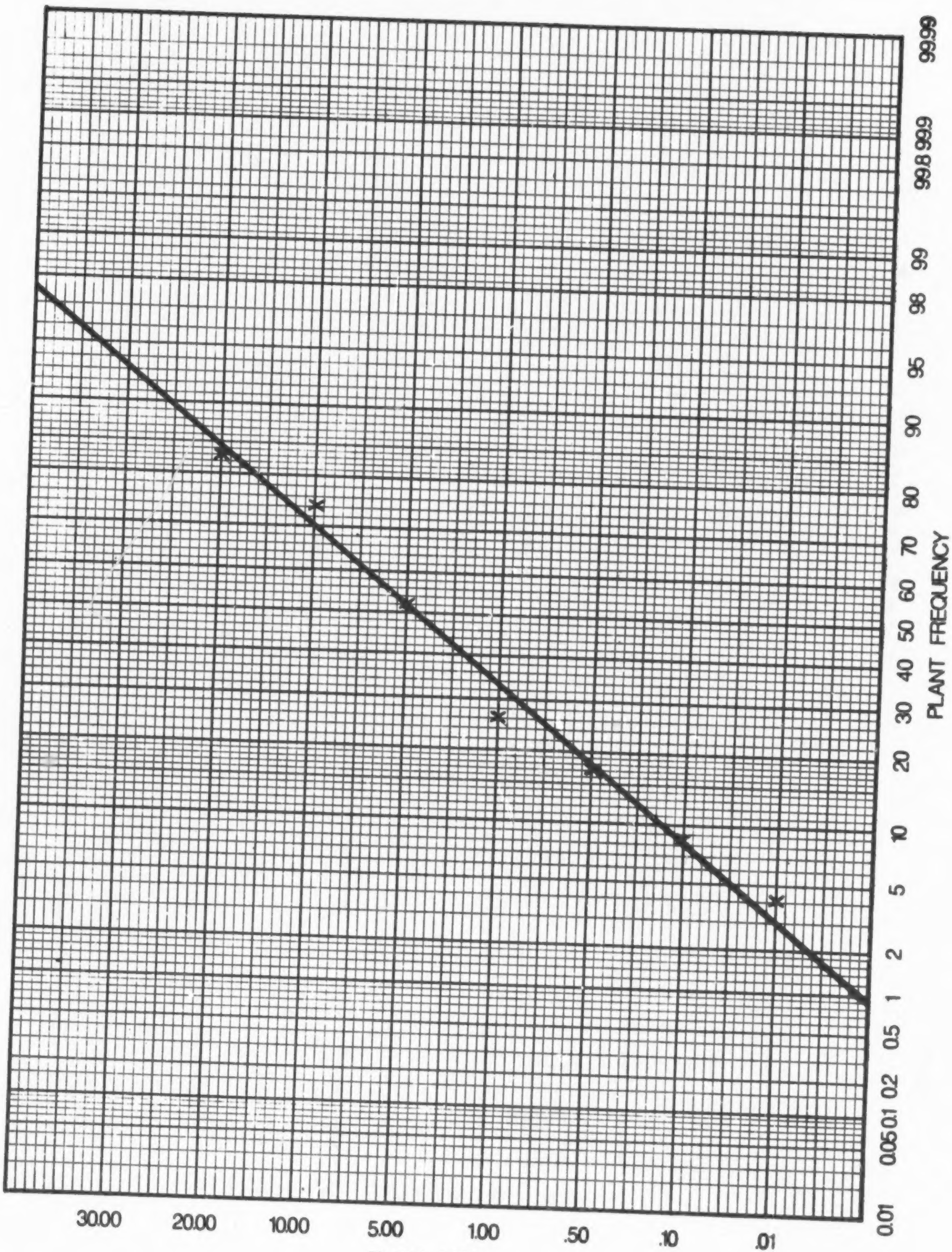

PRODUCTION--THOUSANDS OF TONS/YEAR
1,000
100
2
5
10
15
20
30
40
50
60
70
80
85
90
95
98
PLANT FREQUENCY

FIGURE 3


30.00
20.00
10.00
5.00
1.00
.50
.10
.01
FLOW--MGD
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
PLANT FREQUENCY

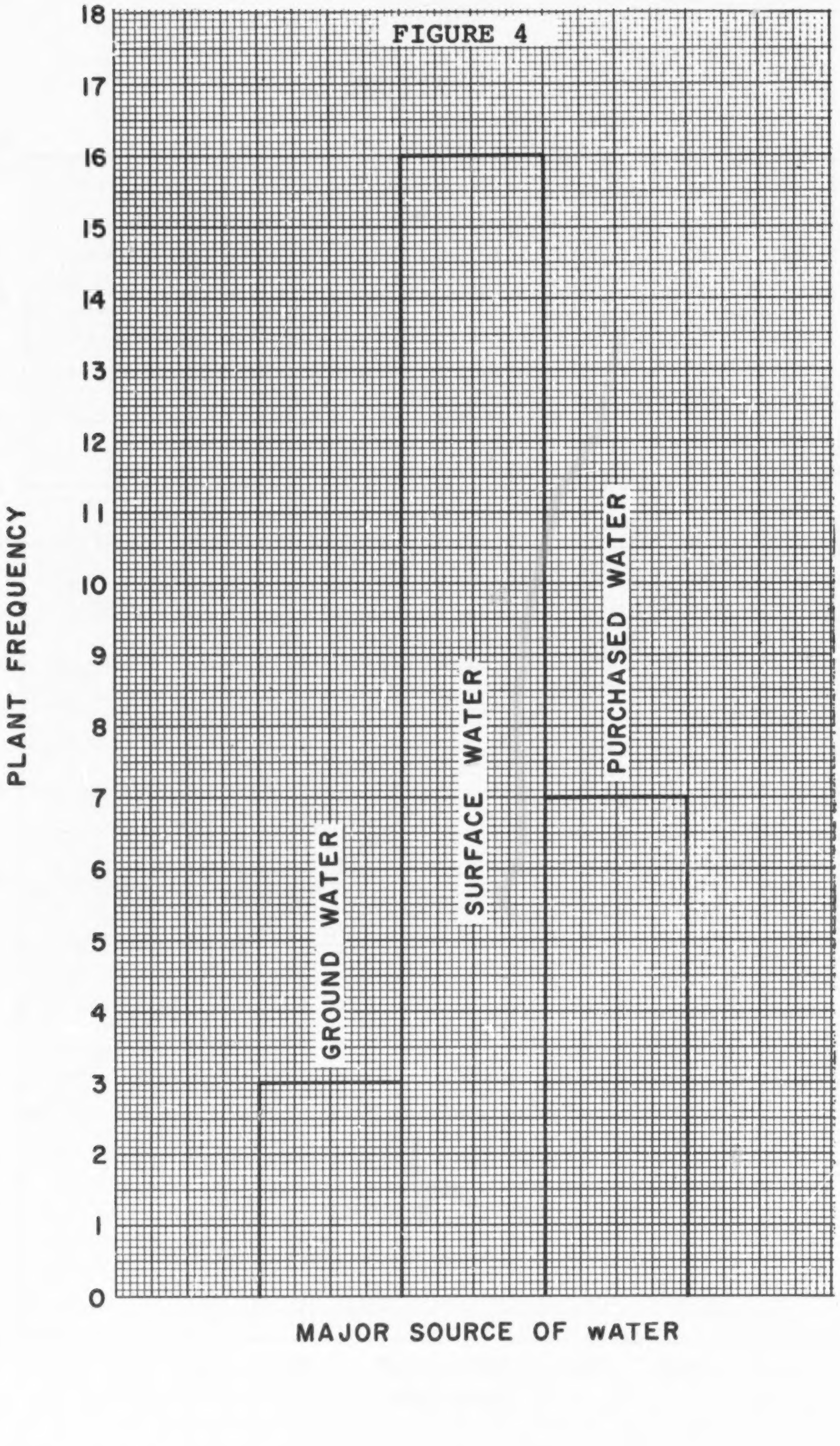


FIGURE 4
PLANT FREQUENCY
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
GROUND WATER
SURFACE WATER
PURCHASED WATER
MAJOR SOURCE OF WATER

FIGURE 5

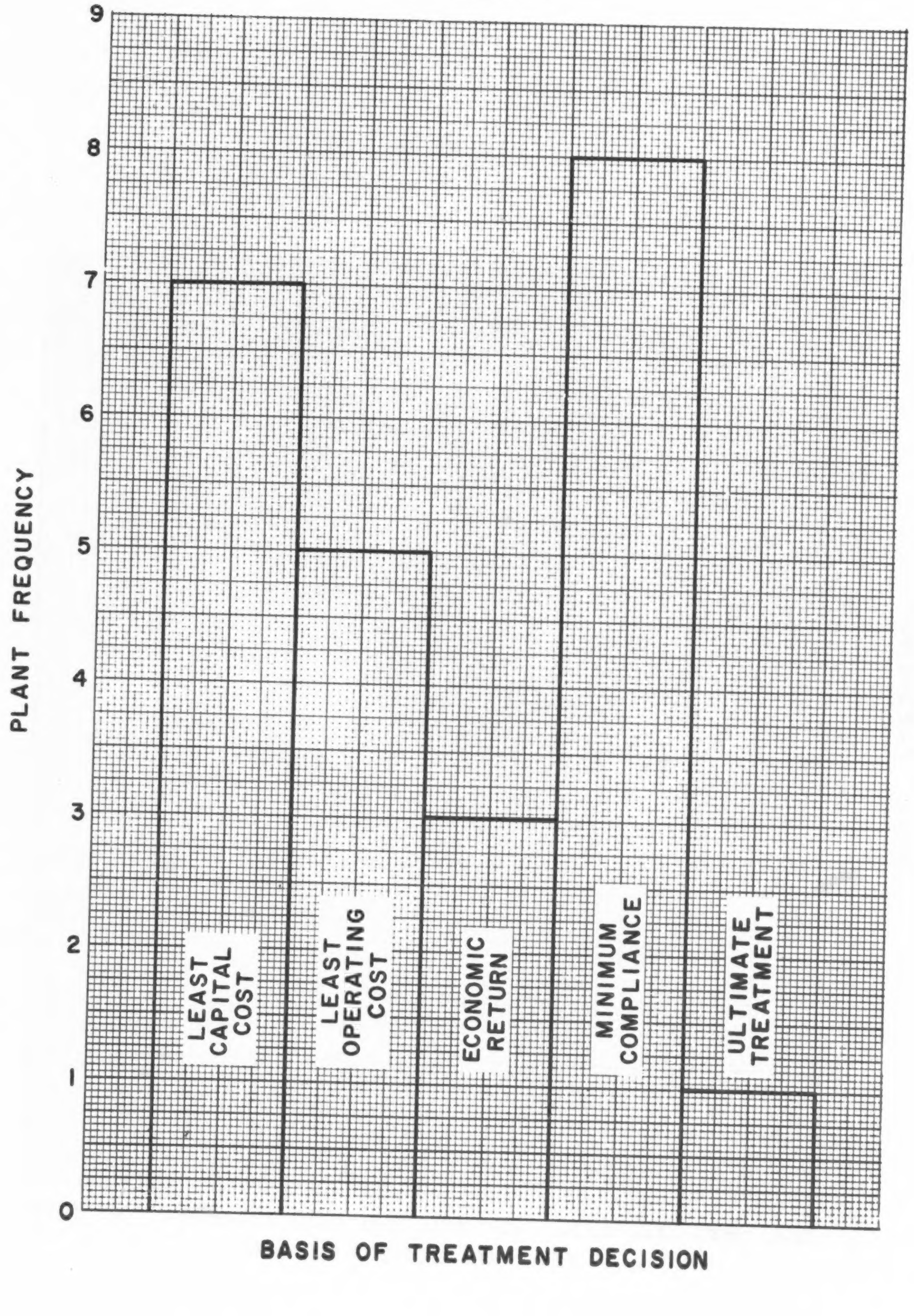

PLANT FREQUENCY
0
1
2
3
4
5
6
7
8
9
LEAST CAPITAL COST
LEAST OPERATING COST
ECONOMIC RETURN
MINIMUM COMPLIANCE
ULTIMATE TREATMENT
BASIS OF TREATMENT DECISION

FIGURE 6

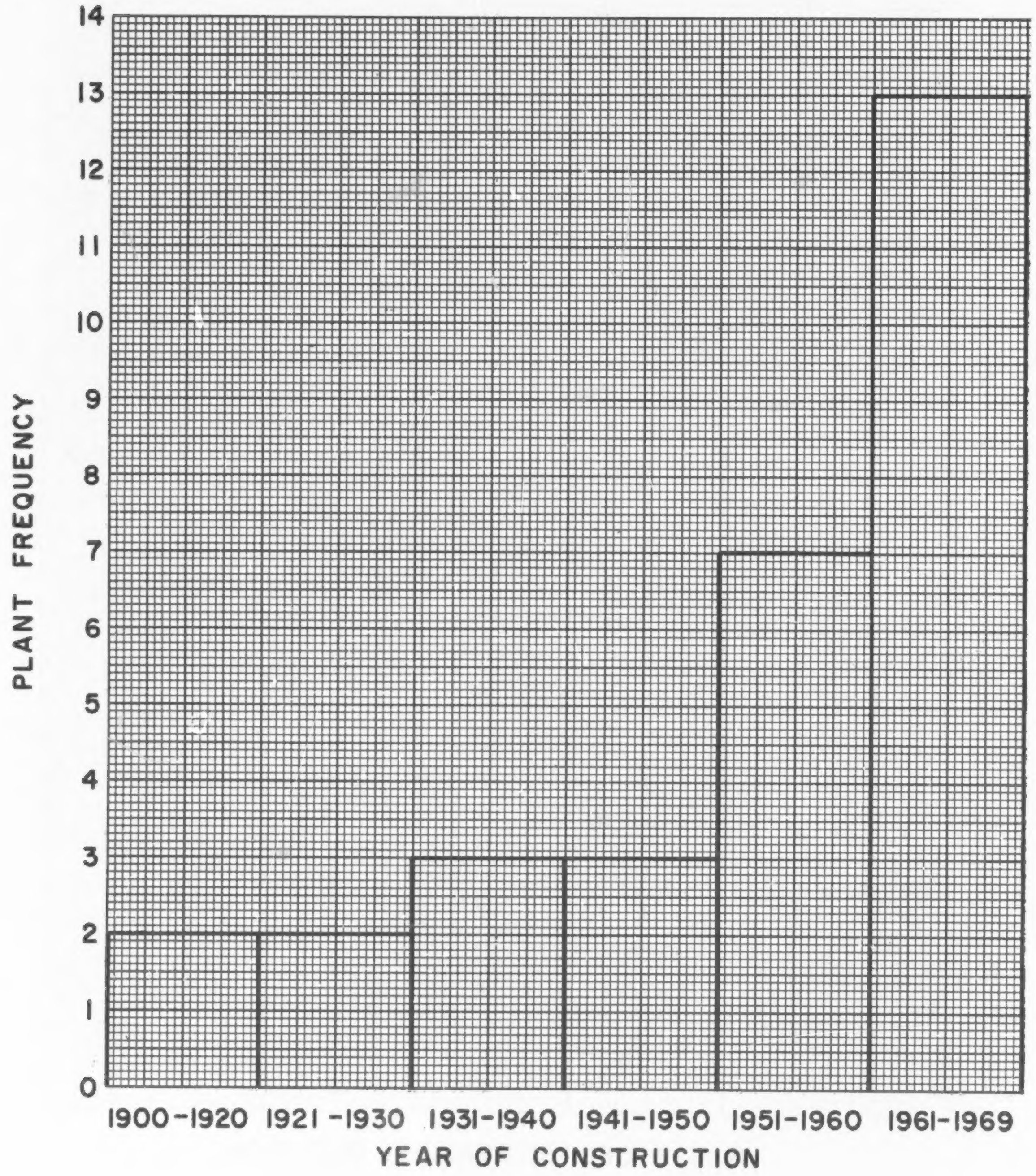

14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
PLANT FREQUENCY
1900-1920
1921 -1930
1931-1940
1941-1950
1951-1960
1961-1969
YEAR OF CONSTRUCTION

FIGURE 7

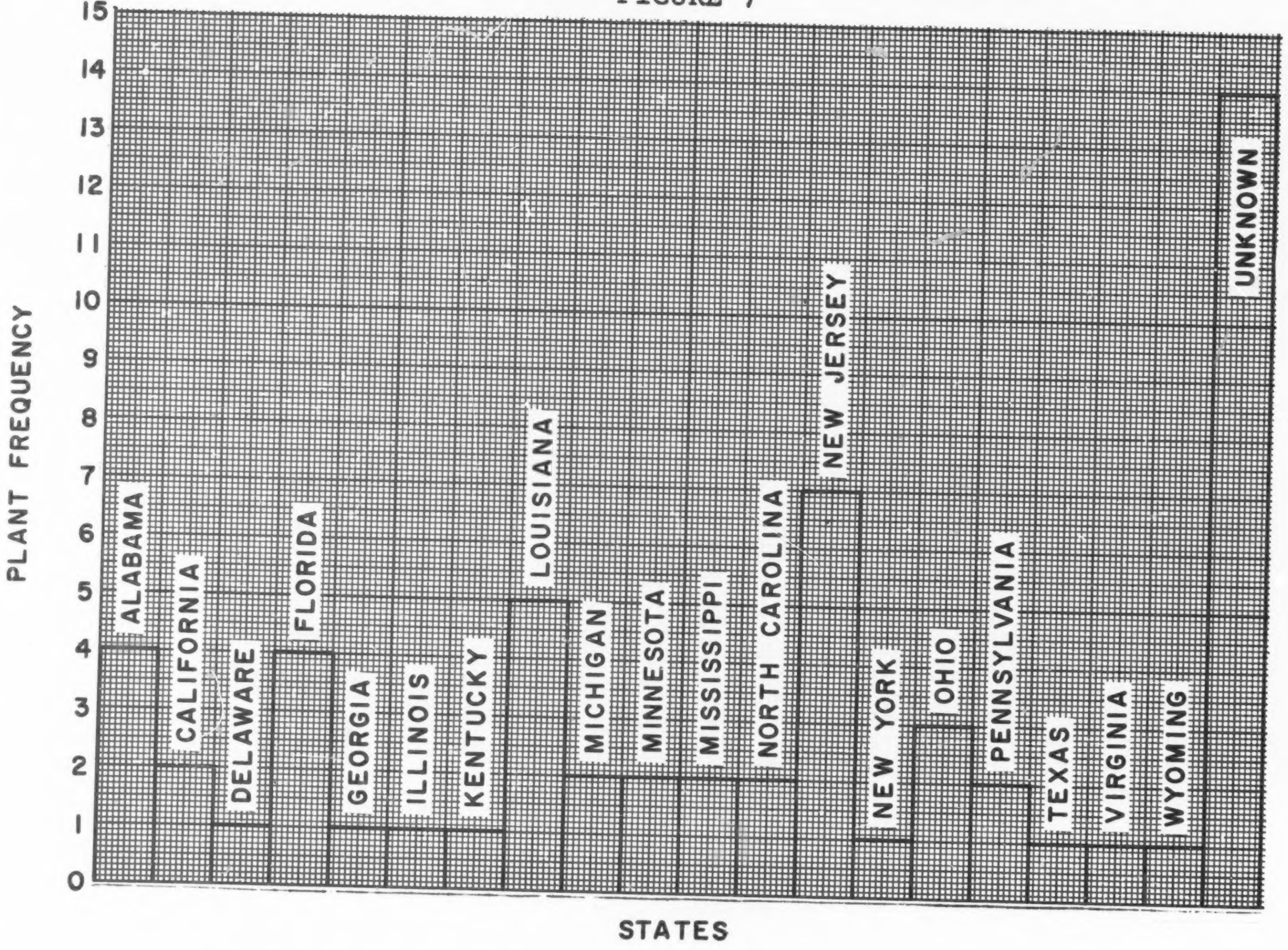
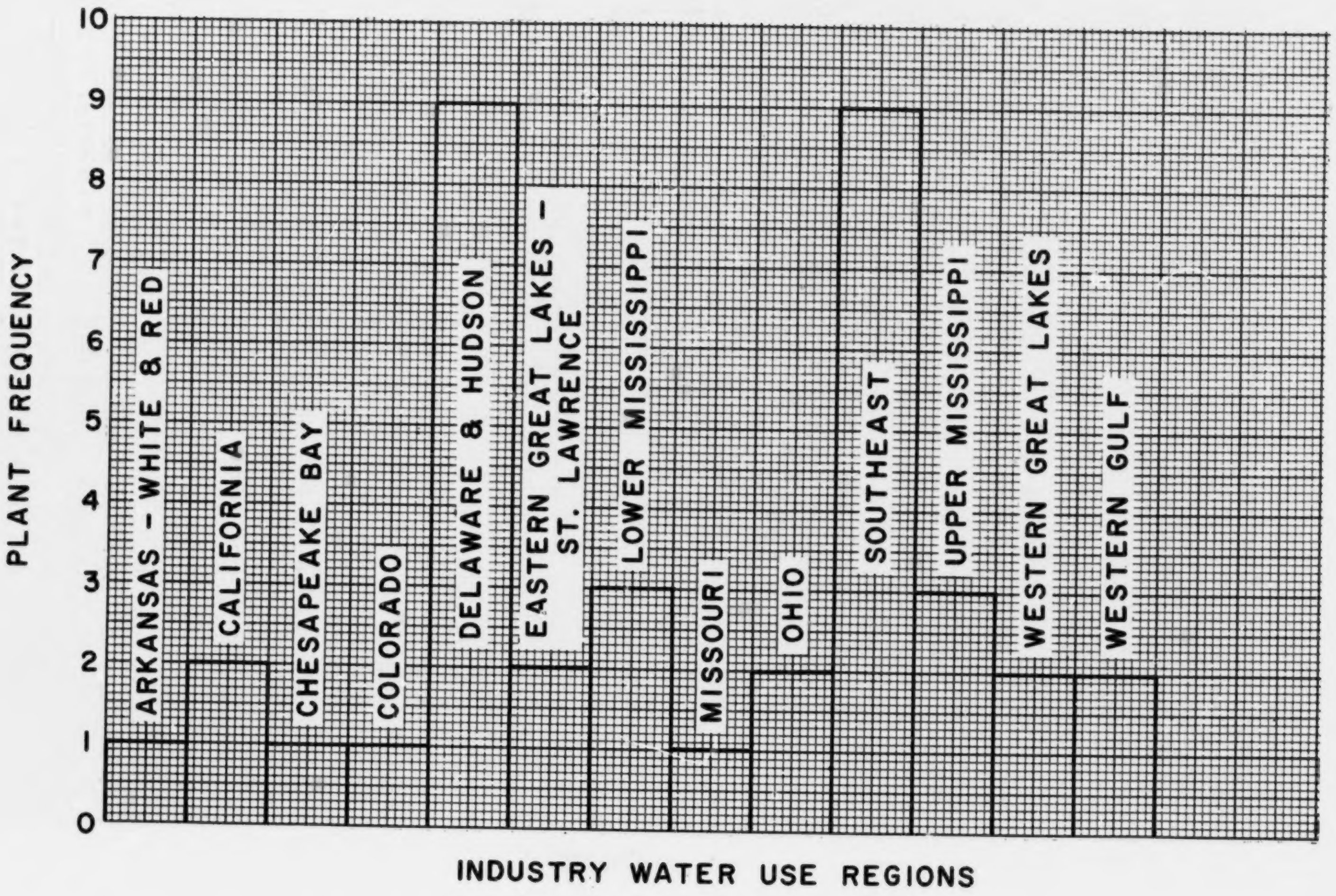

PLANT FREQUENCY
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
ALABAMA
CALIFORNIA
DELAWARE
FLORIDA
GEORGIA
ILLINOIS
KENTUCKY
LOUISIANA
MICHIGAN
MINNESOTA
MISSISSIPPI
NORTH CAROLINA
NEW JERSEY
NEW YORK
OHIO
PENNSYLVANIA
TEXAS
VIRGINIA
WYOMING
UNKNOWN
STATES

FIGURE 8


PLANT FREQUENCY
0
1
2
3
4
5
6
7
8
9
10
ARKANSAS - WHITE & RED
CALIFORNIA
CHESAPEAKE BAY
COLORADO
DELAWARE & HUDSON
EASTERN GREAT LAKES - ST. LAWRENCE
LOWER MISSISSIPPI
MISSOURI
OHIO
SOUTHEAST
UPPER MISSISSIPPI
WESTERN GREAT LAKES
WESTERN GULF
INDUSTRY WATER USE REGIONS

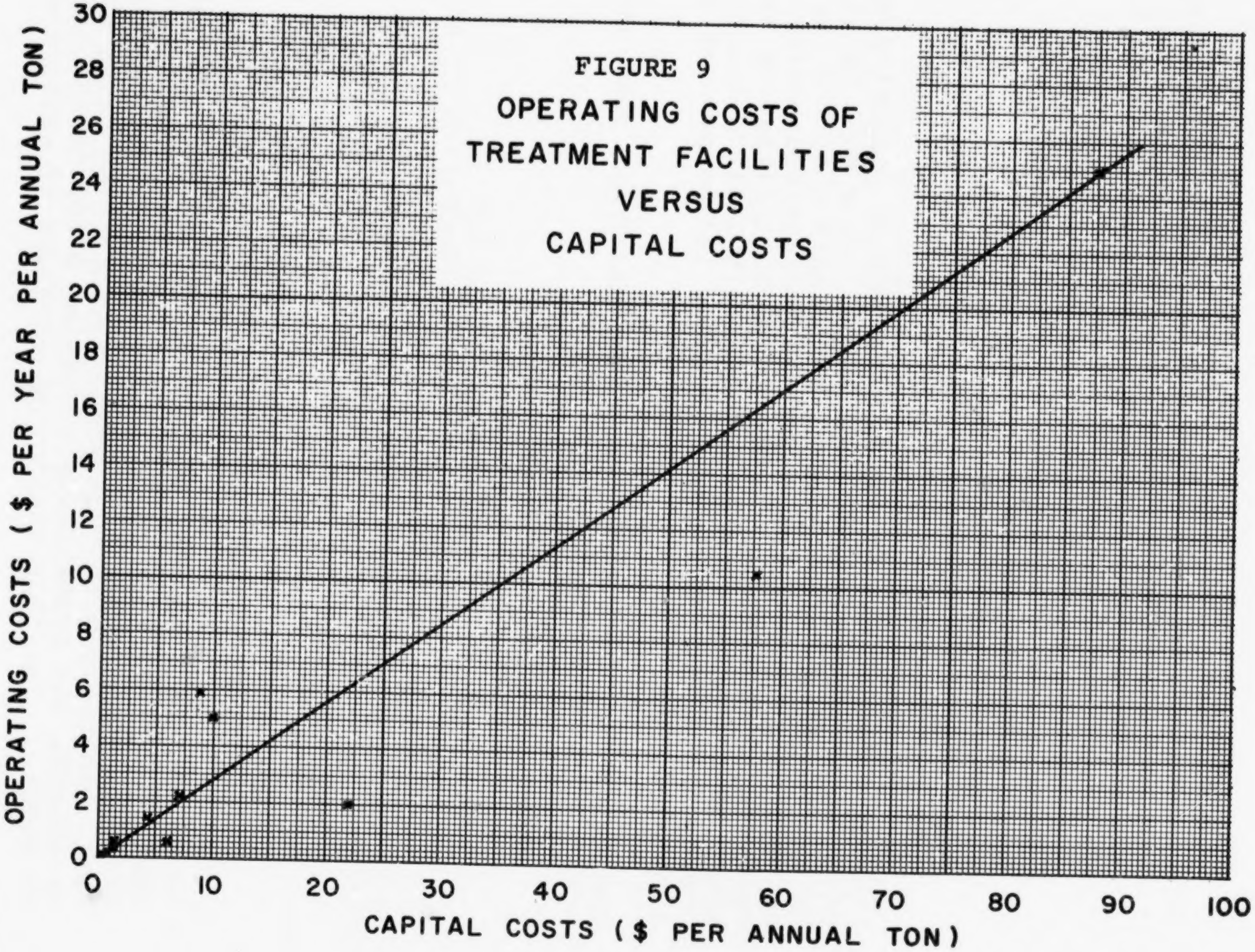


FIGURE 9
OPERATING COSTS OF
TREATMENT FACILITIES
VERSUS
CAPITAL COSTS

CHAPTER IX

COSTS OF UNIT WASTEWATER TREATMENT METHODS

Introduction

The composition of wastes from the inorganic chemical industry are very unpredictable, but the types of pollutant in the waste can be classified under one of the following headings:

1. Acidity or alkalinity
2. Suspended solids
3. Filterable solids
4. Dissolved solids
5. Temperature

Various combinations of the above types of pollution may occur in an inorganic chemical waste. Care must be taken when discussing these types of pollutants that the correct references are used, e.g., the total dissolved solids (TDS) referred to here refers to TDS after neutralization when there is no excess acidity or alkalinity, since a large amount of TDS may be removed or added in the process of neutralization.

The ranges of the values for pollutants found from the industry were as follows:

Process Water

Flow rate	0.5 mgd to 50 mgd
Acidity	200 mg/l (as $CaCO_3$) to 20,000 mg/l
Suspended solids	0-500 mg/l
Dissolved solids	1000-150,000 mg/l

Cooling Water

Flow rate	Up to 150 mgd
Temperature range	140°F-180°F

It is evident from many studies of distribution of pollutant concentration with flow rate that the combination of high pollutant load with high flow rate is improbable. Thus, generally with high process water flow rates such as 50 mgd, the probability of having a TDS of 150,000 mg/l is remote. For this reason, an envelope of extreme values

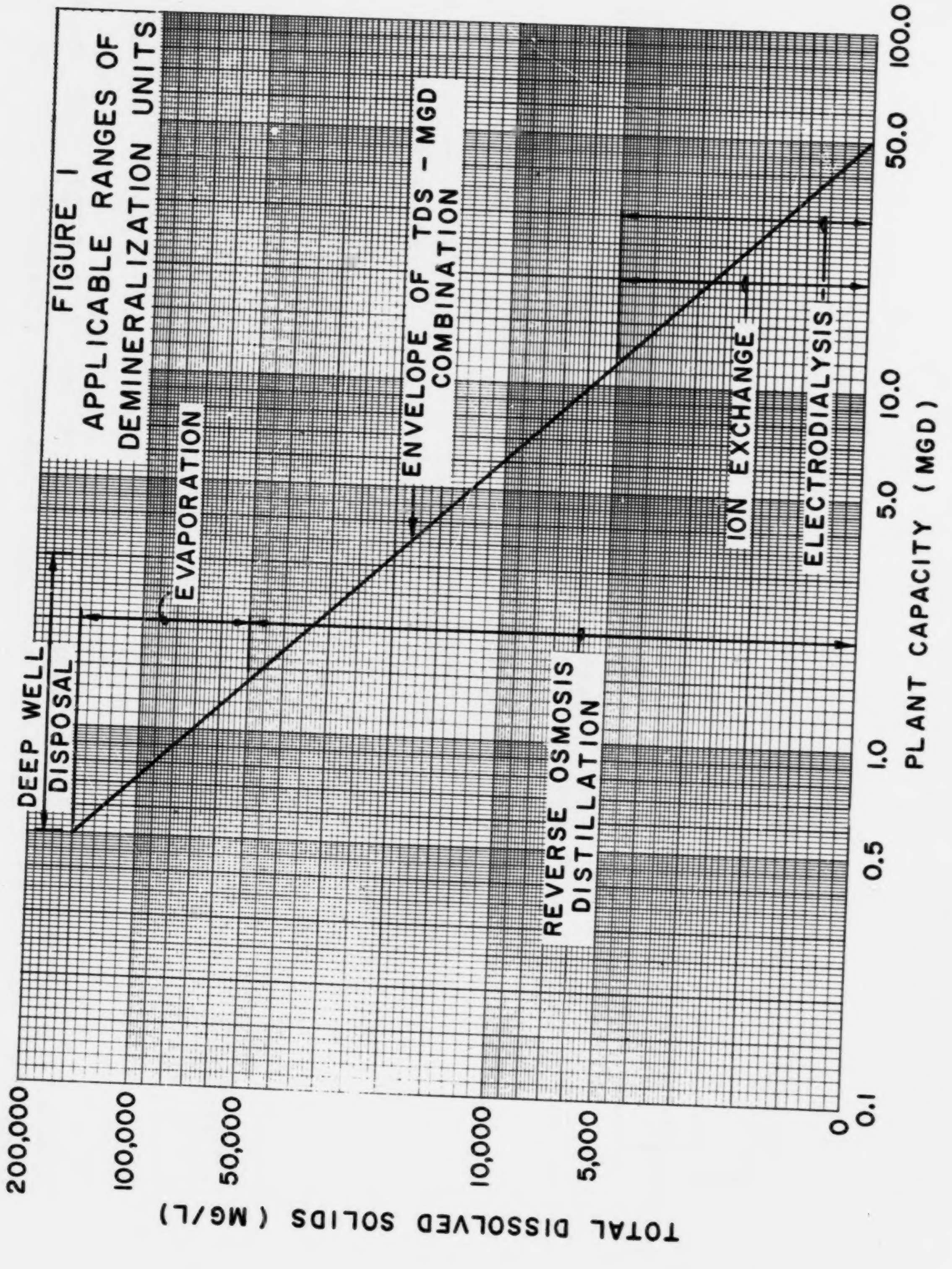


FIGURE I
APPLICABLE RANGES OF DEMINERALIZATION UNITS

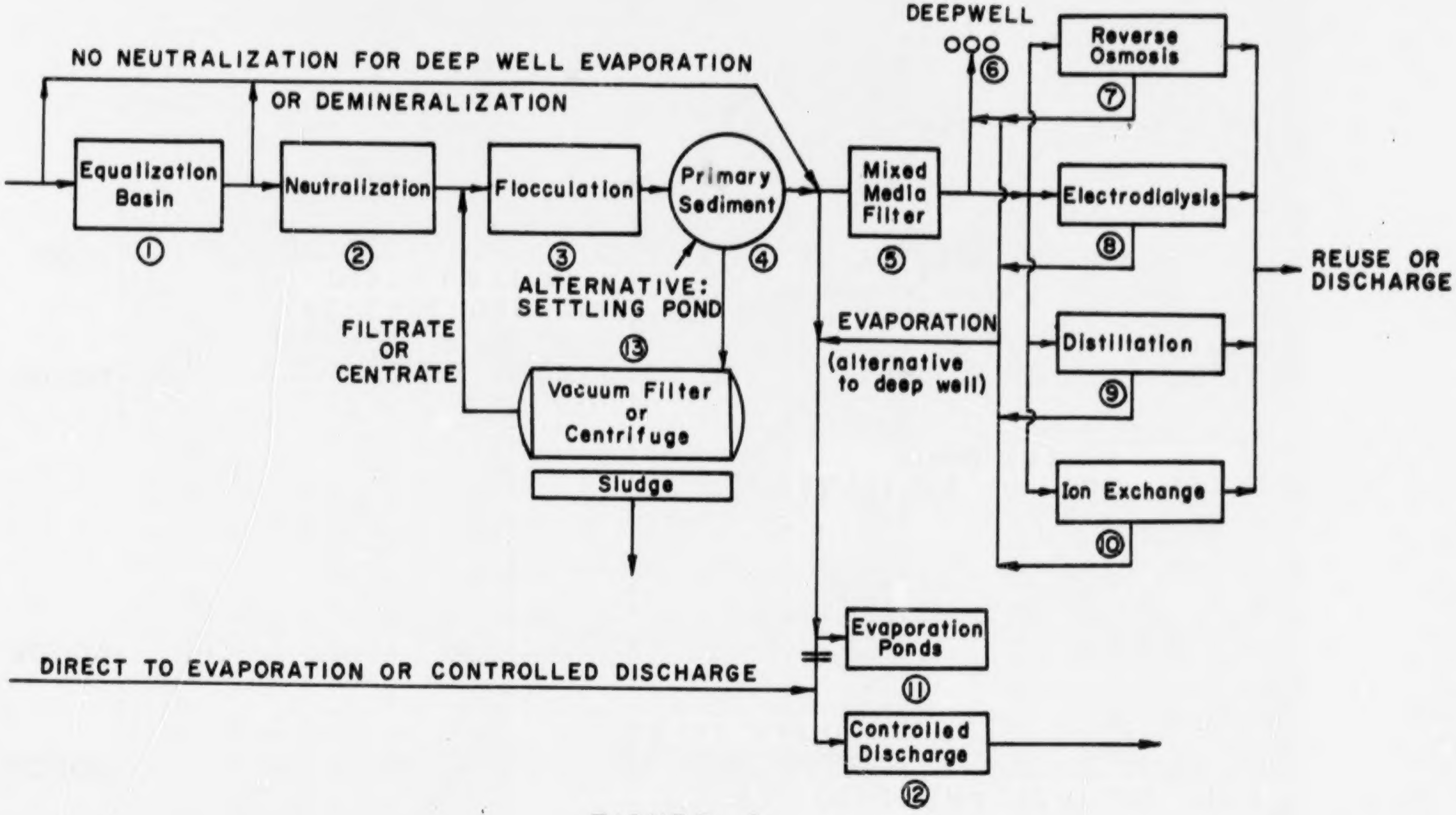

NO NEUTRALIZATION FOR DEEP WELL EVAPORATION
OR DEMINERALIZATION
Equalization Basin
①
Neutralization
②
Flocculation
③
Primary Sediment
④
ALTERNATIVE: SETTLING POND
FILTRATE OR CENTRATE
⑬
Vacuum Filter or Centrifuge
Sludge
Mixed Media Filter
⑤
DEEPWELL
⑥
Reverse Osmosis
⑦
Electrodialysis
⑧
Distillation
⑨
Ion Exchange
⑩
REUSE OR DISCHARGE
EVAPORATION
(alternative to deep well)
Evaporation Ponds
⑪
Controlled Discharge
⑫
DIRECT TO EVAPORATION OR CONTROLLED DISCHARGE

FIGURE 2

SCHEMATIC LAYOUT OF TREATMENT PLANT FOR WASTES FROM THE INORGANIC CHEMICAL INDUSTRY SHOWING VARIOUS POSSIBLE COMBINATIONS OF UNITS

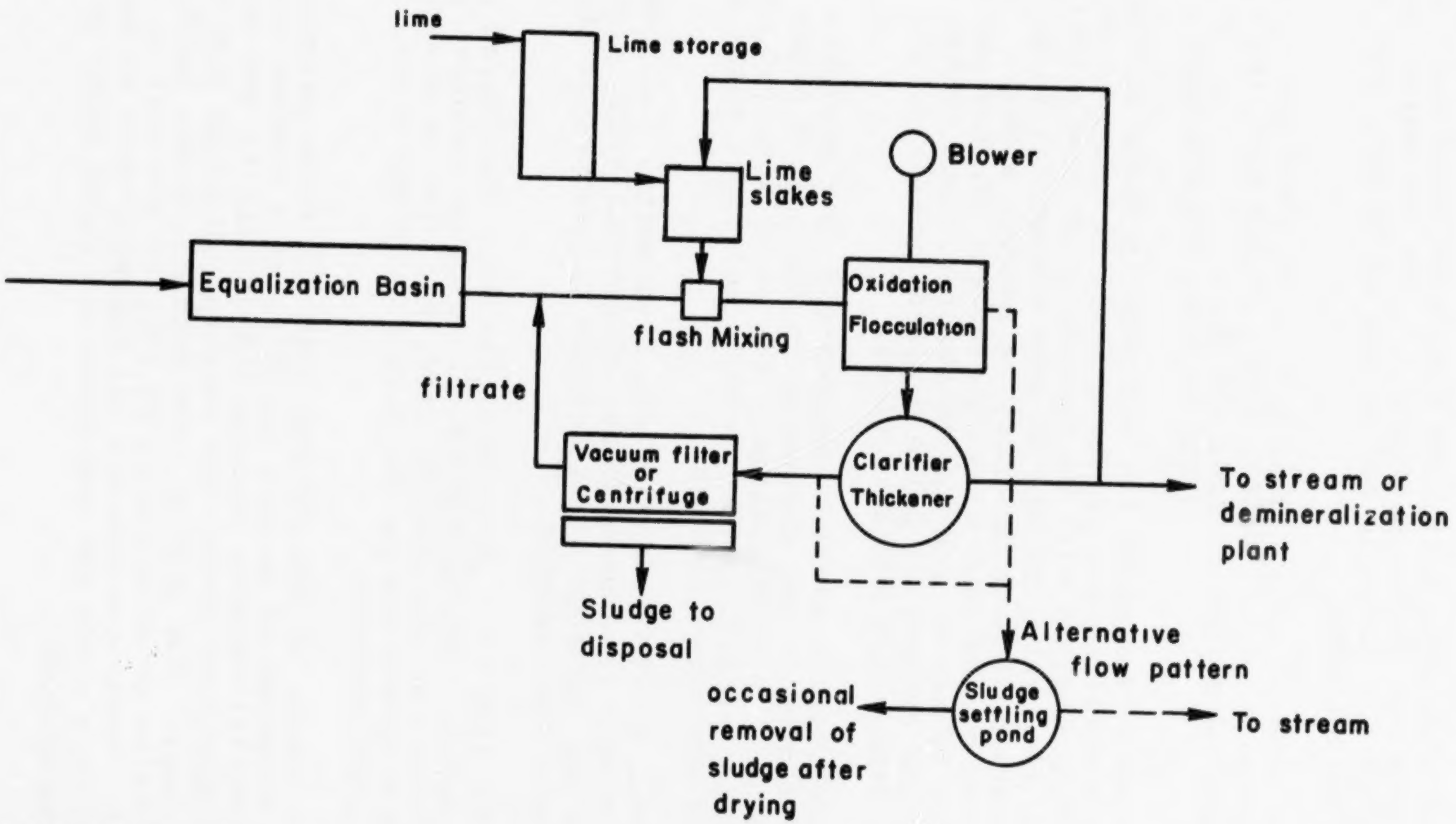

lime
Lime storage
Lime slakes
Blower
Equalization Basin
flash Mixing
Oxidation Flocculation
filtrate
Vacuum filter or Centrifuge
Clarifier Thickener
To stream or demineralization plant
Sludge to disposal
Alternative flow pattern
occasional removal of sludge after drying
Sludge settling pond
To stream

FIGURE 3
FLOW SHEET FOR NEUTRALIZATION PLANT

of TDS and flow rate that have been considered for cost calculations are shown in Figure 1. The following combinations within the triangle and values of acidity were chosen for this cost study:

Flow rate	0.5, 1.0, 10.0, 50.0 mgd
Acidity	500, 1000, 20,000 mg/l (as $CaCO_3$)
Suspended solids	100, 500 mg/l
TDS	3000, 30,000, 150,000 mg/l

The flow sheet suggested for analysis is shown in Figure 2. When neutralization of the acidity is not required, the neutralization plant will be bypassed. At low acidities and a low flow rate, it may be more economical to eliminate neutralization if high TDS must be removed anyway. This will depend on the cost structure of the various units, the quantities of waste, the use to which product wastes may be used, the economy of brine disposal versus solids disposal, and other such considerations.

The neutralization plant suggested for cost analysis is shown in Figure 3, and discussed in Appendix E under the heading of neutralization. The plant included aeration flocculation to precipitate ferrous and other metal ions. The costs are shown in Table I.

The removal of TDS in any of the five units, i.e., deep well disposal, reverse osmosis, electrodialysis, distillation, or ion exchange might require filtration of the liquid as a pretreatment.

All of the last four processes that were considered will produce brine. The concentration of brine produced will depend first, on the process used, but also on the cost of brine disposal and on the possible market value of the usable water produced.

For this study, it was assumed that all brine produced will be disposed of in deep wells or at a similar cost. Other disposal methods include disposition to the ocean, solar evaporation ponds, and evaporation ponds that use applied heat. The process used depends on the location and the brine concentration, as well as the cost of brine disposal. These factors are too unpredictable to be included in a study and the costs are given based on the above assumptions.

TABLE I

TREATMENT LEVEL I
NEUTRALIZATION COSTS INCLUDING EQUALIZATION AND SLUDGE DEWATERING

Flow mgd	Acidity mg/l	SS mg/l	Capital Cost $1000	Operating Cost ¢/1000 gal
0.5	500	100	120.0	15
0.5	500	500	145.0	20
0.5	1,000	100	184.0	27
0.5	1,000	500	190.0	29
0.5	20,000	100	514.0	108
0.5	20,000	500	514.0	108
1.0	500	100	183.0	14.5
1.0	500	500	236.0	25
1.0	1,000	100	300.0	26
1.0	1,000	500	320.0	26
1.0	20,000	100	807.0	103
1.0	20,000	500	807.0	103
10.0	500	100	1,120.0	11
10.0	500	500	1,290.0	12.5
10.0	1,000	100	1,540.0	18
10.0	1,000	500	1,640.0	20
50.0	500	100	3,420	10.5
50.0	500	500	3,980	11

NOTE: Costs based on the sum of unit processes 1, 2, 3, and 4 in Figure 1.

TABLE II

TREATMENT LEVEL II
DEMINERALIZATION COSTS INCLUDING PREFILTRATION AND BRINE DISPOSAL

				CAPITAL COSTS					OPERATING COST			
					Demineralization							
Flow mgd	TDS mg/1	Total Product Water @ 500 mg/1 mgd	Brine Disposal mgd	Filtration $1000	Process No.	Cost $1000	Brine Disposal Cost $1000	Total Cost +35%	Filtration (¢/ 1000 gal)	Demineralization (¢/1000 gal)	Brine (¢/1000 gal)	Total Cost (¢/1000 gal)
0.5	3,000			66	6	430	-	670	8.5	35.0	-	43.5
		0.35	0.15	66	7	640	360	1,439	8.5	40.0	18.0	66.5
		0.25	0.25	66	8	455	398	1,240	8.5	65.0	24.0	97.5
		0.47	0.03	66	10	1,700	190	2,551	8.5	25.0	16.0	49.5
				-	11[1]	40	-	40		5.0		5.0
		0.45	0.05	66	9	806	388	1,701	8.5	98.0	16.0	122.5
0.5	30,000			66	6	430		670	8.5	35.0	-	43.5
		0.167	0.33	66	7	784	412	1,704	8.5	75.0	29.0	112.5
		-		-	11	40		40		5.0		5.0
		0.25	0.25	66	9	806	397	1,713	8.5	98.0	24.0	130.5
0.5	150,000	-		66	6	430		670				43.5
		-		-	11	40		40				5.0
1.0	3,000	-		102	6	290		529	7.0	25.6		
		0.75	0.25	102	7	1,120	397	2,185	7.0	31.0	13.5	51.5
		0.50	0.50	102	8	896	431	1,929	7.0	54.0	18.3	79.3
		0.95	0.05	102	10	3,020	360	4,700	7.0	33.3	8.5	48.8
		-		-	11	100		75	-			5.0
		0.9	0.1	102	9	1,610	370	2,810	7.0	85.0	11.0	103.0
	30,000	0.33	0.67	102	7	1,340	447	2,550	7.0	50.0	20.6	77.6
		0.50	0.50	102	9	1,610	430	2,892	7.0	85.0	18.3	110.3
10.0	3,000	7.5	2.5	450	7	6,700	740	10,651	3.0	18.5	4.5	26.0
		5.0	5.0	450	8	6,400	925	10,496	3.0	38.0	8.0	49.0
		8.0	2.0	450	9	9,070	646	13,724	3.0	38.0	3.0	44.0
		9.5	0.5	450	10	14,800	430	21,160	3.0	30.0	1.0	34.0
				-	11	410	-	410	-	5.0	-	5.0
10.0	30,000	3.3	6.7	450	7	8,400	1,200	13,567	3.0	25.0	10.0	38.0
		0.50	0.50	450	9	9,070	925	14,100	3.0	38.0	8.0	49.0
50.0	3,000	45.0	5.0	1,350	7	29,100	925	42,356	2.0	15.0	2.0	19.0
		45.0	5.0	1,350	9	34,700	925	49,920	2.0	22.0	2.0	26.0

[1] For evaporation ponds, consider only those states or areas where the evaporation rate is twice the average annual rainfall. Consider land value a nominal $100/acre. Capital costs in thousand dollars.

The literature was searched for the amount of brine produced by the desalting units under "normal" operating conditions. Assumptions were made based on this information and the quantities used are shown in Table II, which presents the capital and operating costs for various combinations of capacities and processes. Available data usually refers to brine production as a by-product of potable water production and not of waste treatment as such. For potable water production, the disposal of brine is of secondary importance.

Where land is available and the evaporation rate exceeds the average annual rainfall by a sufficient margin, solar evaporation ponds will be an economical treatment method that will not require pretreatment. Operating costs will also be low.

In the regions of regular (as compared with seasonal) rainfall, it may be more economical to store the waste in lagoons and discharge to the stream only at sufficiently high stream flow rates to provide the necessary dilutions. This method is limited to a small number of locations in the country. The size of the ponds will be determined by the flow rate and variance of the stream flow, the TDS content of the stream and the later use of the stream. It is difficult to base a cost function on these factors and for this reason, only the method is shown.

Cooling water would normally need only to be cooled down sufficiently so as not to raise the stream temperature unduly. Cooling towers may be constructed based on the mean low flow condition in summer or cooling ponds may be used if land is cheap.

The calculated costs are summarized in two separate tables mentioned in the foregoing. Table I considers neutralization for Treatment Level I only, and Table II considers the dissolved solids removal and brine disposal costs of waste treatment at Treatment Level II.

CHAPTER X

COSTS VERSUS EFFLUENT QUALITY RELATIONSHIPS

The data from the survey of 59 plants was not sufficiently complete in regard to effluent quality to construct any statistically significant relationship between numbers of plants, and effluent quality parameters such as acidity, suspended solids and dissolved solids.

The methods of treatment currently employed by the inorganic chemical industry, as previously discussed, are quite limited in number and, in general, involve as a group (1) equalization, (2) neutralization, (3) flocculation, (4) sedimentation, and (5) sludge dewatering. This combination then is judged to account for the typical situation and to be equivalent to approximately 27% level of treatment, the reported average industry level.

The nature of the waste substances, inorganic soluble salts, and the treatment processes available to reduce or remove such salts is such that there are, practically speaking, no intermediate levels of treatment. That is to say, treatment for removal of dissolved salts, if applied at all, produces a quality of effluent water equivalent or better than plant influent supply water. An increase in the level of treatment of inorganic chemical plant effluents thus goes in one step from the 27% level involved in neutralization and suspended solids removal to 100% removal of the contaminants. For design purposes, demineralization effluent quality is set at 500 mg/l.

On the basis of the range of volumes of plant effluents and the foregoing considerations of only two levels of treatment, a series of likely design combinations was constructed, one for each level and the capital and operating costs determined. Table I in Chapter IX presented the cost data for Treatment Level I which, as previously mentioned, is judged equivalent to 27% removal. Table II in Chapter IX presented the cost data for Treatment Level II which represents 100% removal with ultimate disposal of the residues. Figure 2 in Chapter IX is a schematic diagram showing the generalized layout for treatment of water from the inorganic chemical industry. The numbers identifying each unit process correspond to the unit process numbers in Tables I and II. Note from Figure 2 in Chapter IX that the brine from the demineralization processes is taken to deep well disposal or to solar evaporation alternatively. Figure 1 in Chapter IX shows the applicable ranges of the alternative demineralization units employed in the construction of Table II data.

An examination of the information shown in the aforementioned Tables I and II of Chapter IX, coupled with a judgment as to the typical level of wastes to be encountered, leads to the selection of 1000 ppm acidity and 100 ppm suspended solids as representative of present practice to establish the basis of industry cost projections covered in Chapter XI for Treatment Level I. Similarly, 3000 ppm TDS is judged representative of wastes for application of Treatment Level II. In this latter connection, the capital and operating costs for demineralization process No. 7 reverse osmosis, were chosen for projection purposes even though simple deep well disposal is clearly lower in both costs.

It is believed that any generalization developed based upon wide use of large volume deep well disposal for Treatment Level II would be misleading since such general application of deep wells is considered impractical.

CHAPTER XI

PROJECTED INDUSTRY COSTS

According to the U.S. Census Bureau's 1963 publication, Water Use in Manufacturing, inorganic chemical plants reported annual water intake volumes as shown in Table I. **These are the latest available data.**

TABLE I

NUMBERS OF INORGANIC CHEMICAL PLANTS BY WATER INTAKE VOLUME-1963 (1)

		INTAKE VOLUMES millions of gallons per year				
SIC No.	Total	less than 1	1-9	10-19	20-99	more than 100
2812	38	4	2	1	2	29
2813	421	197	106	36	33	49
2816	76	32	13	4	7	20
2819	524	189	98	39	60	138
2851	1224	981	162	28	38	15
2871	241	104	50	24	32	31
2879	253	218	23	2	7	3
2892	58	28	4	5	4	17
TOTAL	2835	1753	458	139	183	302

(1) U.S. Census Bureau, Census of Manufactures-1963, "Water Use in Manufacturing"

Water discharges from large plants (intakes of more than 20 million gallons per year) are given in Table II.

TABLE II

WATER DISCHARGES FROM LARGE INORGANIC CHEMICAL PLANTS-1968 (1)

SIC No.	Total Discharge (10^9 gal/yr)	Discharge to Municipal Sewers (10^9 gal/yr)	Percent to Sewers
2812	364.1	47.2	13.0
2813	80.8	2.7	3.3

TABLE II (cont.)

SIC No.	Total Discharge (10^9 gal/yr)	Discharge to Municipal Sewers (10^9 gal/yr)	Percent to Sewers
2816	91.5	1.0	1.1
2819	468.0	42.6	9.1
2851	6.5	4.6	70.8
2871	97.4	0.3	0.3
2879	Not available	Not available	-
2892	143.1	<50 million gal.	0.0

(1) U.S. Census Bureau, Census of Manufactures-1968, "Water Use in Manufacturing"

Assuming that all plants having intakes of less than 20 million gallons per year discharge to municipal sewers, the total industry discharge to municipal sewers in 1963 is estimated to have been 48.0 billion gallons. Discharges from large plants to other than municipal sewers are given in Table III.

TABLE III

LARGE INORGANIC CHEMICAL PLANT DISCHARGES
OTHER THAN TO MUNICIPAL SEWERS-1968 (1)

SIC No.	No. of Plants	Discharge 10^9 gal/yr	Average Discharge 10^9 gal/yr
2812	31	316.9	10.22
2813	65	78.1	1.20
2816	24	90.5	3.77
2819	223	425.4	1.91
2851	32	1.9	0.06
2871	42	97.1	2.31
2879	Not available	Not available	-
2892	21	143.1	6.81
TOTAL	438	1153.1	2.63

(1) U.S. Census Bureau, ibid

Water intakes and usages by purpose are given in Table IV.

TABLE IV

LARGE INORGANIC CHEMICAL PLANT INTAKES AND USAGE, BY PURPOSE, 1968 (1)

	Billions of Gallons per Year					
SIC No.	Total Intake	Process	Cooling	Other	Gross Use	Use Rate
2812	386.4	18.9	361.0	6.5	574.3	1.49
2813	92.3	5.3	86.5	0.6	193.7	2.10
2816	95.4	21.2	68.5	5.7	125.8	1.32
2819	514.8	75.2	404.5	35.2	1432.0	2.78
2851	6.8	2.7	2.9	1.3	9.8	1.44
2871	113.7	24.2	64.5	24.9	474.1	4.17
2879	------------------Not Available----------------					
2892	152.3	28.0	116.2	8.2	186.8	1.23
TOTAL	1361.7	175.5	1104.1	82.4	2996.5	2.20

(1) U.S. Census Bureau, ibid

Assuming that contaminated wastewaters will be equivalent to that withdrawn for process and other non-cooling purposes, and that percentage disappearances are constant for all purposes, the total of such wastewaters for large plants in the industry in 1968 is estimated to have been 237.5 billion gallons to other than municipal sewers. The average contaminated wastewater discharge from large plants to other than municipal sewers is thus estimated to have been 1.485 mgd. The average discharge to municipal sewers from large plants is estimated to have been 0.616 mgd.

Numbers of plants, values of shipments, and price indexes for the inorganic chemical industry in 1958, 63, 66, 67, 68 and 69 are given in Table V.

TABLE V

THE INORGANIC CHEMICAL INDUSTRY

SIC		No. of Plants		Value of Shipments		Price Index
No.	Yr.	Total	+20 Emp.	($1000)	($1000-'58)	'57-59=100
2812	58	n/a	32	425,431	425,431	100.0
2813	58	n/a	178	262,581	262,581	100.0
2816	58	n/a	57	412,011	412,011	100.0
2819	58	n/a	301	2,146,254	2,146,254	100.0
2851	58	n/a	600	1,753,923	1,753,923	100.0
2871	58	n/a	207	611,103	611,103	100.0
2879	58	n/a	101	347,628	347,628	100.0
2892	58	n/a	58	169,699	169,699	100.0
2812	63	37	34	652,120	687,890	94.8
2813	63	460	148	425,388	448,722	94.8
2816	63	97	52	484,768	532,127	91.1
2819	63	678	326	3,493,870	3,685,517	94.8
2851	63	1,779	650	2,456,361	2,696,335	91.1
2871	63	279	198	863,701	864,566	99.9
2879	63	329	108	476,661	477,138	99.9
2892	63	67	47	283,298	286,160	99.0
2812	66	n/a	n/a	782,661	817,828	95.7
2813	66	n/a	n/a	549,687	574,386	95.7
2816	66	n/a	n/a	581,774	645,698	90.1
2819	66	n/a	n/a	3,845,232	4,018,006	95.7
2851	66	n/a	n/a	2,970,403	3,296,785	90.1
2871	66	n/a	n/a	1,183,321	1,133,449	104.4
2879	66	n/a	n/a	692,741	663,545	104.4
2892	66	n/a	n/a	469,413	468,009	100.3
2812	67	44	40	719,800	741,298	97.1
2813	67	507	156	588,700	606,282	97.1
2816	67	98	60	549,300	602,303	91.2
2819	67	718	358	4,248,400	4,375,283	97.1
2851	67	1,701	680	2,911,400	3,192,325	91.2
2871	67	213	184	1,196,900	1,168,848	102.4
2879	67	344	115	817,000	797,852	102.4
2892	67	92	52	647,000	615,019	105.2
2812	68	n/a	n/a	754,000	766,260	98.4
2813	68	n/a	n/a	613,000	622,967	98.4
2816	68	n/a	n/a	650,000	704,989	92.2
2819	68	n/a	n/a	4,200,000	4,268,293	98.4
2851	68	n/a	n/a	3,221,000	3,493,492	92.2
2871	68	n/a	n/a	1,091,820	1,088,554	100.3
2879	68	n/a	n/a	869,288	866,688	100.3
2892	68	n/a	n/a	667,057	606,415	110.0

TABLE V (Continued)

SIC No.	Yr.	No. of Plants Total	No. of Plants +20 Emp.	Value of Shipments ($1000)	Value of Shipments ($1000-'58)	Price Index '57-59=100
2812	69	n/a	n/a	792,000	804,878	98.4
2813	69	n/a	n/a	653,000	663,618	98.4
2816	69	n/a	n/a	690,000	748,373	92.2
2819	69	n/a	n/a	4,305,000	4,375,000	98.4
2851	69	n/a	n/a	3,459,000	3,751,627	92.2
2871	69	n/a	n/a	1,149,686	1,146,247	100.3
2879	69	n/a	n/a	924,922	922,156	100.3
2892	69	n/a	n/a	687,736	625,215	110.0

Using the data in Table V and assuming that (1) the number of plants having water intakes of over 20 million gallons, (2) those having more than 20 employees, and (3) the total number of plants will remain in the 1963-67 ratio, numbers of plants are estimated by year in Table VI.

TABLE VI

NUMBERS OF PLANTS IN THE INORGANIC CHEMICAL INDUSTRY

Year	Val. of Ship ($1000-'58)	No. of Plants (more than 20 Emp.)	No. of Plants (more than 20 mil.gal/yr)	No. of Plants (Total)
1958	6,128,630	1,534	476	3,656
1963	9,669,455	1,563	485	3,726
1966	11,617,706	1,617	501	3,853
1967	12,099,210	1,645	510	3,717
1968	12,417,658	1,672	518	3,778
1969	13,037,114	1,699	527	3,839

In Table VII, productions of inorganic chemicals are given for 1968 and projected by year through 1974.

TABLE VII

PROJECTED PRODUCTION OF INORGANIC CHEMICALS, 1968-1974

(millions of tons)

SIC No.	1968	1969	1970	1971	1972	1973	1974
2812	24	25	26	28	30	32	34
2813 1/	17.5	20.1	23.7	28.5	34.3	40.8	47.9
2816	1.20	1.25	1.29	1.37	1.44	1.51	1.59
2819	70	72	74	77	80	84	88
2851 2/	3.51	3.74	3.93	4.16	4.41	4.68	4.96
2871	41.5	41.0	42.3	43.9	46.1	48.0	49.9
2879	0.20	0.20	0.19	0.18	0.18	0.17	0.15
2892 3/	0.98	1.04	1.08	1.11	1.15	1.20	1.27

1/ From Chemical and Engineering News 1968 production and Resource Engineering Associates projections

2/ From Resource Engineering Associates projection and sp. gr.=1.0

3/ From 1963 production and values and Resource Engineering Associates projections

Production in the industry, numbers of plants, and waste discharges are projected from the above data in Table VIII. Numbers of plants were estimated by a detailed analysis of the total industry production and the ratios of plant sizes and SIC distributions in 1963. These estimates were updated according to the data of the 1967 Census of Manufactures. Eighty five percent of the total production is assumed to have been produced in large plants, as is indicated by the plant capacity data in Appendix A.

TABLE VIII

THE INORGANIC CHEMICAL INDUSTRY, 1963-74 1/

	1963	1968	1969	1970	1971	1972	1973	1974
No. of Plants, Total	3458	3514	3574	3597	3631	3670	3711	3755
No. of Small Plants 2/	3012	3036	3088	3109	3139	3173	3209	3247
No. of Large Plants 3/	446	478	486	488	492	497	502	508
Production Total (billion lbs)	-	317.8	328.7	345.0	368.4	395.2	424.7	455.5
Production, Large Plants (billion lbs)	-	270.1	279.4	293.3	313.1	355.9	361.0	387.2
Production, Small Plants (billion lbs)	-	47.1	49.3	51.7	55.3	59.3	63.7	68.3
Municipal Sewer Discharges (billion gal)	59.0	108.1	112.2	117.6	125.3	134.1	143.8	154.0
Large Plants (billion gal)	53.7	98.4	102.1	106.9	113.9	121.9	130.7	139.9
Small Plants (billion gal)	5.3	9.7	10.1	10.7	11.4	12.2	13.1	14.1
Wastewater, Not to Sewers, Large Plants (bil. gal)	211.8	257.9	267.7	280.5	298.9	320.1	343.5	367.9
Cooling Water, Not to Sewers, Large Plants (bil. gal)	922.9	1104.1	1145.6	1200.9	1279.8	1370.9	1468.5	1572.5
Gross Water Use, Large Plants (billion gal)	2466.0	2996.5	3110.4	3262.2	3480.1	3730.3	4006.0	4294.0
Value of Shipments, Total (bil. 1958 $)	9.669	12.418	13.037	-	-	-	-	-

1/ Based upon 1963 and 1968 water use data and projected production

2/ <20 million gallons per year

3/ >20 million gallons per year

The data in Table VIII are based upon the water uses reported in 1963 and 1967, and discharges are estimated from gross water uses based upon projected production. In 1968, large plants in the inorganic chemical industry used (including recirculation) 2996 billion gallons of water for all purposes and discharged 1362 billion gallons, taking in 1362 billion gallons. The entire chemical industry (SIC 28) reported a use of 9416 billion gallons that year; the inorganic chemical industry thus used about 31.8% of the total, slightly less than the 32.5% as earlier reported. A 1967 survey of the chemical industry by the Manufacturing Chemists Association (2) indicated a gross water use of 8340 billion gallons that year. These data and the data in Table VIII indicate water uses in the inorganic chemical industry of 2711 and 2890 billion gallons per year, respectively. Inorganic chemicals have shown a long term decrease in percentage of the overall chemical market from 49.5% in 1958 to 40% in 1968.

Data from the 1958, 1963, and 1967 Census of Manufactures and from the 1967 MCA survey are shown in Table IX. These data generally apply to large plants in the chemical industry.

(2) "Toward a Clean Environment," Manufacturing Chemists Association, 1967.

TABLE IX

WATER USE DATA, 1958-67

	1958 1/	1963 1/	1967 2/	1968 3/
CHEMICALS & ALLIED PRODUCTS:				
Intake, bil. gal.	3240	3889	4269	4476.2
Gross Use, bil. gal.	5225	7577	8340	9415.8
Discharges, bil. gal.	3061	3662	4085	4175.1
Use Rate	1.61	1.95	1.95	2.104
Discharges as % of Use	58.5	48.3	48.9	44.3

TABLE IX (Continued)

	1958 1/	1963 1/	1967 2/	1968 3/
INORGANIC CHEMICALS:				
Intake, bil. gal.		1287		1361.7
Gross Use, bil. gal.		2466		2996.5
Discharges, bil. gal.		1134.7		1153.0
Use Rate		1.92		2.20
Discharges as % of Use		46.0		38.5

1/ U.S. Bureau of Census, 1963 Census of Manufactures, Water Use in Manufacturing
2/ Ref (2) MCA Survey, ibid
3/ "Water Use in Manufacturing," Census of Manufactures

Table X shows projections of production and discharges which incorporate all of the above data from Tables VIII and IX.

Data from the 1967 MCA survey of the chemical industry are given in Table XI and ranges of plant capacities in the inorganic chemical industry are shown in Table XII. Table XII indicates an average plant capacity of 0.783 billion pounds per year and a median capacity of 0.319 billion pounds per year. This compares favorably with the 1968 average capacity in Table X of 0.565 billion pounds per year. The data in Table XI indicate an average discharge from large plants of wastewater to other than municipal sewers of 0.657 billion gallons per year per plant in 1967 for the chemical industry as a whole.

TABLE X

THE INORGANIC CHEMICAL INDUSTRY, 1963-74 1/

	1963	1968	1969	1970	1971	1972	1973	1974
Large Plants, Average Data:								
Production, bil lbs/yr/plant	-	0.565	0.575	0.601	0.636	0.676	0.719	0.762
Wastewater, bil gals/yr/plant	0.475	0.539	0.551	0.575	0.608	0.644	0.684	0.724

1/ Ref (1) U.S. Census Bureau, ibid
Ref (2) Manufacturing Chemists Association 1967 Survey, ibid

TABLE XI

1967 MCA SURVEY DATA
THE CHEMICAL INDUSTRY (2)

No. of Plants	987
Capital Investment in Wastewater Treatment through 1966	$385,268,000
Capital Investment in Wastewater Treatment, 1962-1966	$140,640,000
Capital Investment in Wastewater Treatment, 1967-1971	$235,700,000
Annual Operating Cost, 1967	$59,638,000
Water Withdrawals	11.696 bil. gal/day
Water Used	22.848 bil. gal/day
Discharge to Surface Waters:	
Cooling Water	9.224 bil. gal/day
Process Wastewater	1.777 bil. gal/day
Discharge to Public Sewers:	
Cooling Water	0.078 bil. gal/day
Process Wastewater	0.114 bil. gal/day
Inorganic Waste Discharges:	
To Surface Waters:	
Dissolved	135.3 mil. lbs/day
Undissolved	11.65 mil. lbs/day
To Public Sewers:	
Dissolved	2.156 mil. lbs/day
Undissolved	0.192 mil. lbs/day
Total Discharged	149.3 mil. lbs/day
Total Discharged with No Treatment	205.1 mil. lbs/day

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(2) Manufacturing Chemists Association 1967 Survey, ibid

TABLE XII

RANGES OF CHEMICAL PLANT PRODUCTION CAPACITIES [1]

Product	Capacity Range, tons/day
Caustic Potash	13.7 - 98.6
Caustic Soda	300 - 7800
Chlorine	180 - 7050
Soda Ash	205 - 10274
Titanium Dioxide	49.3 - 474
Ammonium Nitrate	30.1 - 1164
Nitric Acid	43.8 - 1096
Phosphoric Acid	47.4 - 1342
Phosphorous	16.4 - 389
Sodium Dichromate	41.1 - 247
Sodium Sulfate	21.9 - 753
Superphosphate	63.0 - 959
Ammonium Phosphate	19.2 - 630
Potash	27.4 - 1699
Calcium Carbide	54.8 - 822
Hydrofluoric Acid	27.4 - 137
Sodium Sulfite	8.2 - 397

[1] Industry Product Profiles, Appendix C

Numbers of plants in the chemicals and allied products industries in 1963 are shown in Table XIII by industry segments and by intake water volumes.

TABLE XIII

NUMBERS OF PLANTS IN THE CHEMICAL INDUSTRY, 1963

	Large Plants (more than 20 mil. gal)	Small Plants (less than 20 mil. gal)
Industry Total [1]	1129	6382
Organic Chemicals Industry [2]	211	550
Inorganic Chemicals Industry [3]	446	2187
Other Industry Segments	472	3645

1/ 1963 Census of Manufactures
2/ Ref (3) FWPCA Organic Chemicals Industry, ibid
3/ Present study

Data from the 1967 survey of the chemical industry by the Manufacturing Chemists Association as shown in Table XI are extended on an annual basis and given in Table XIV.

TABLE XIV

CHEMICAL INDUSTRY SURVEY DATA, 1967 (2)

No. of Plants	987
Total Employment	393,657
Capital Investment in Wastewater Treatment through 1966	$385,268,000
Capital Investment in Wastewater Treatment, 1962-1966	$140,640,000
Capital Investment in Wastewater Treatment Projected, 1967-1971	$235,700,000
Annual Operating Cost, 1967	$59,638,000
Annual Manpower Requirements, 1967	2096.1 man-years
Annual Water Intake, bil. gal.	4269
Annual Water Use, bil. gal	8340
Use Rate	1.95
Plant Effluents:	
Cooling Water, to Public Sewers, bil. gal	28.33
Process Wastewater, to Public Sewer, bil. gal.	41.65
Cooling Water, to Surface Waters, bil. gal.	3367
Process Wastewater, to Surface Waters, bil. gal.	648.6
Total Effluents, bil. gal	4085
Contaminants in Effluents to Surface Waters:	
Dissolved Inorganics, mil. lbs.	49370
Undissolved Inorganics, mil. lbs.	4252
Dissolved Organics, mil. lbs.	1284
Undissolved Organics, mil. lbs.	155.5
Contaminants in Effluents to Public Sewers:	
Dissolved Inorganics, mil. lbs.	786.9
Undissolved Inorganics, mil. lbs.	70.1
Dissolved Organics, mil. lbs.	292
Undissolved Organics, mil. lbs.	74.8

TABLE XIV (cont.)

Total Contaminants Produced:	
Inorganics, mil. lbs.	74857
Organics, mil. lbs.	4191

(2) MCA 1967 Survey, ibid

The chemical industry, other than those segments defined as "inorganic chemicals" and as "organic chemicals," includes operations producing inorganic and organic compounds which appear in effluents. Assuming (1) that process wastewaters from the inorganic chemical industry contain only inorganic contaminants, (2) that process wastewaters from the organic chemical industry contain only organic contaminants, and (3) that effluents from other segments contain proportionate amounts of each wastewater volume, the characteristics of the industry's discharge are estimated below in Table XVI from the 1967 MCA survey, the 1963 census data, the 1969 FWPCA study of the organic chemicals industry, and the 1967 census data.

Table XV shows the estimated numbers of plants and wastewater discharges in the chemical industry in 1967, based upon the above three data sources.

TABLE XV

CHEMICAL PLANT SIZES AND DISCHARGES-1967

	Industry Segment			
	Inorganic	Organic	Other	Total
Numbers of Plants:				
Total	3454	833	3542	7829
Large ($>$20 mgy)	470	231	485	1186
Small ($<$20 mgy)	2974	602	3067	6643
Wastewater, Large Plants:				
Not to Sewers (bil. gal)	248	383	148	779
Discharge to Sewers (bil. gal).	104	78.2	39.3	221.5

TABLE XVI

CHEMICAL INDUSTRY DISCHARGES-1967

	Industry Segment Discharges			
	Inorganic	Organic	Other	Total
Discharges to Public Sewers:				
Inorganics (mil. lbs)	989.0	-	41.0	1030
Organics (mil. lbs)	-	304.5	136.5	441
Discharges to Surface Waters:				
Inorganics (mil. lbs)	48498	-	14925	63423
Organics (mil. lbs)	-	1474	256	1730

Using the data in Tables XV and XVI and the MCA survey data, prorating costs and manpower requirements on the basis of wastewater discharges and relative contaminant removals, the data in Table XVII are estimated for large plants in the chemical industry in 1969.

TABLE XVII

CHEMICAL INDUSTRY COSTS AND MANPOWER-1969

	Industry Segment			
	Inorganic	Organic	Other	Total
Investment, mil. $	122.488	399.773	110.291	632.552
Operating Costs, mil. $/yr.	18.960	61.880	17.072	97.912
Manpower Use, man-years/yr.	666	2175	601	3442

Assuming, as discussed in Chapter X, that the average plant in the industry produces wastewaters containing 100 ppm suspended solids, 1000 ppm acidity and 3000 ppm dissolved solids, and that present practice as defined by the MCA survey (27% removal of contaminants) is achieved by neutralization with equalization and sludge dewatering, the following unit costs are as shown in Chapter IX for the typical plant. Reverse osmosis is the method of choice for demineralization (100% removal of contaminants) as indicated by reasonable capital and operating costs. Deep well disposal and evaporation ponds, although lower in cost, are not always applicable due to local conditions and, hence, were not shown.

% Removal Contaminants	Capital Costs $/1000 gpd	Operating Costs ¢/1000 gal
27 (SS and Acidity)	300	26.0
100 (TDS)	2185	51.5

Assume also that the capital costs involved in discharging to public sewers are those entailed in removing suspended solids and neutralizing acidity. Therefore, based upon the flows shown in Table X and the above assumptions on unit capital costs, the capital costs for the inorganic chemicals industry are estimated as shown in Table XVIII and XIX. The capital costs for the 27% removal level shown in 1969 thus represent the in place capital for the existing levels of treatment in the inorganic chemical industry in 1969 dollars.

TABLE XVIII

CUMULATIVE INORGANIC CHEMICAL INDUSTRY CAPITAL COSTS, 1969-1974

%	Costs in Millions of 1969 Dollars					
Removal	1969	1970	1971	1972	1973	1974
27	314.3	329.8	352.2	377.8	405.9	435.4
100	1898.8	1992.4	2127.6	2281.7	2451.8	2632.4

In terms of current dollars, and using an average of 3.6% annual increase in the price level, total industry capital costs are projected in Table XIX.

TABLE XIX

CUMULATIVE INORGANIC CHEMICAL INDUSTRY CAPITAL COSTS, 1969-1974

%	Costs in Millions of Current Dollars					
Removal	1969	1970	1971	1972	1973	1974
27	314.3	341.7	377.9	420.1	467.7	519.4
100	1898.8	2062.2	2281.9	2537.1	2823.5	3118.5

It should be underscored that the capital costs shown in Table XVIII and in Table XIX for 1969 are in terms of 1969 dollars. The capital costs for the chemical industry shown in Table XVII are in terms of sums spent over perhaps the preceding 30 years. Allowing for price increases over such a period of time, the costs shown in Table XVII for the inorganic segment of the industry compare well with that portion of the 1969 costs in Table XVIII for the 27% level of treatment attributable to large plants. Assuming that the operating costs associated with discharges to municipal sewers at 10 cents per 1000 gpd, projected industry operating costs are given in Table XX in 1969 dollars and in Table XXI in current dollars.

TABLE XX

PROJECTED ANNUAL INORGANIC CHEMICAL
INDUSTRY OPERATING COSTS

% Removal	Costs in Millions of 1969 Dollars 1969	1970	1971	1972	1973	1974
27	86.1	90.3	96.5	103.5	111.2	119.3
100	165.4	173.4	185.1	198.7	213.4	228.9

TABLE XXI

PROJECTED ANNUAL INORGANIC CHEMICAL
INDUSTRY OPERATING COSTS

% Removal	Costs in Millions of Current Dollars 1969	1970	1971	1972	1973	1974
27	86.1	93.6	103.5	115.1	128.1	142.3
100	165.4	179.6	198.7	221.0	245.9	273.2

The plant survey data shown in Chapter VIII, based upon costs per unit of wastewater flow, indicate that the industry costs to achieve 85% removal of contaminants other than dissolved solids in large plants in 1969 are as follows:

In place capital costs =
$223 x 1,131,520 (1000 gpd) = $252,328,960
In place operating costs =
$58.49 x 1,131,520 (1000 gpd) = $ 66,182,605/year

Addition of the costs associated with discharges to municipal sewers by small plants show that the total industry costs for the level of treatment described can be estimated as follows:

In place capital costs =
259.5 million dollars
In place operating costs =
67.0 million dollars per year

The above costs would represent an overall removal of wastewater contaminants of approximately 23%, i.e., 85% removal of contaminants constituting 27% of the total in the wastewaters. Comparison of these figures with those in Tables XVIII and XX shows good agreement and tend to support the projections made.

CHAPTER XII

QUALITATIVE MANPOWER REQUIREMENTS

Information regarding qualitative manpower requirements can be found in Chapter XII, pages 76-96 of the study entitled "Inorganic Chemicals Industry Profile," which was completed under Federal Water Pollution Control Administration Contract No. 14-12-592 and published as a part of "The Economics of Clean Water - Volume Three," United States Department of the Interior, March 1970.

CHAPTER XIII

QUANTITATIVE MANPOWER REQUIREMENTS

Information regarding quantitative manpower requirements can be found in Chapter XIII, pages 97-121 of the study entitled "Inorganic Chemicals Industry Profile," which was completed under Federal Water Pollution Control Administration Contract No. 14-12-592 and published as a part of "The Economics of Clean Water - Volume Three," United States Department of the Interior, March 1970.

APPENDIX A

INORGANIC CHEMICAL INDUSTRY SURVEY DATA

TABLE I

Plant Number	Critical Pollutant	Efficiency	Capital Cost Per 1000 GPD	Operating Cost Per 1000 GPD	Capital Cost Per Ton/Year	Operating Cost Per Ton/Year	Wastewater GPD/Ton/ Year
00013	SO4	-	-	-	-	-	-
00016	Acidity	99	1736.11	-	2.66	-	1.53
00017	Acidity	99	2083.33	-	3.62	-	1.74
00018	-	-	-	-	-	-	18.33
00026	Acidity	99.5	1666.67	300.00	57.80	10.40	34.68
00027	-	-	6.92	1.04	1.28	0.19	185.70
00030	SS	98	-	-	-	-	336.00
00033	Cl	-	-	-	-	-	7.21
00034	SS	-	260.41	-	2.17	-	8.34
00037	Cl	-	-	-	-	-	7.22
00040	Oil	73	1.06	0.10	22.00	2.00	20736.00
00042	-	-	1.29	1.28	1.42	0.21	166.66
00050	Temp.	-	411.37	140.27	4.15	1.42	10.09
00051	SS	95	20.83	-	1.74	-	83.33
00052	SS	95	83.33	5.55	8.82	5.88	105.88
00053	SS	-	1500.00	600.00	1.44	0.58	0.96
00054	BOD	90	152.17	1.04	0.44	<0.01	2.90
00055	BOD	45	583.33	166.66	87.50	25.00	150.00
00056	SS	99.8	116.66	36.66	7.00	2.20	60.00
00057	-	-	12.00	1.00	6.00	0.50	500.00
00058	-	0	0.00	0.00	0.00	0.00	40000.00
00059	SS	90	5.00	2.50	10.00	5.00	2000.00
00060	BOD	50	387.10	32.26	0.41	0.03	1.07
00061	-	99	307.69	116.92	0.31	0.12	1.00
00062	-	0	0.00	0.00	0.00	0.00	42.42
00063	BOD	70	1.67	0.35	0.01	<0.01	6.48
00064	Acidity	-	-	-	-	-	64.11

NOTES: The following abbreviations are used:

BOD - Biochemical Oxygen Demand
SS - Suspended Solids
Cl - **Chlorides**
Temp. - Temperature
SO4 - Sulfates

APPENDIX B

INORGANIC CHEMICAL INDUSTRY
PRODUCT PROFILES

Individual Product Profiles
Flowchart of a Standard Medium-Pressure Air-Separation Plant
Flowchart for Diaphragm Caustic Soda and Chlorine Cell
Flowchart for 60% Nitric Acid from Ammonia
Typical Flowchart for Sulfur-Burning Contact Plant
Flowchart for Smokeless Powder
Flowchart for Mixing of Paint
Flowchart for Titanium Dioxide

Sources of Data:

Chemical Profiles
Oil, Paint and Drug Reporter
"Future Inorganic Chemical Growth Patterns"
R. N. Rickles, Noyes Development
Chemical Week
Bureau of the Census
TVA

SIC 2812 (ALKALIES AND CHLORINE)

Caustic Potash

Producer	Capacity [1]
Allied, Syracuse, N.Y.	30,000
Diamond, Delaware City, Del.	12,500
Diamond, Muscle Shoals, Ala.	22,000
Dow, Pittsburg, Calif.	10,000
FMC, South Charleston, W. Va.	10,000
Hooker, Niagara Falls, N.Y.	36,000
IMC, Niagara Falls, N.Y.	22,000
Monsanto, Anniston, Ala.	25,000
Monsanto, East St. Louis, Ill.	29,000
Pennsalt, Calvert City, Ky.	5,000
PPG, Corpus Christi, Tex.	5,000
PPG, New Martinsville, W. Va.	10,000
Total	216,500

[1] 1000's of tons/year (90% basis)

Production: 1969: 180,000 tons (90% basis)
1974: 216,000 tons (90% basis)

Uses: Soaps and detergents (including use as tetrapotassium pyrophosphate), potassium carbonate and other potassium chemicals.

Processes: By the electrolysis of potassium chloride.

Waste Problems: No major change is expected. See chlorine.

Caustic Soda

Producer	Capacity [1]
Alcoa	450
Allied	1,200
Diamond	2,030
Dow	7,800
FMC	850
GAF	525
Goodrich	575
Hooker	1,780

Caustic Soda (cont.)

Producer	Capacity 1/
Kaiser	600
Monsanto	350
Olin	1,870
Pennsalt	1,100
PPG Industries	2,860
Shell	275
Stauffer	913
Vulcan	330
Weyerhaeuser	300
Wyandotte	1,870
Others	1,070
Total	26,748

1/ tons/day

Production: 1969: 8,500,000 tons/year
1974: 11,500,000 tons/year

Uses: Chemicals, pulp and paper, aluminum, rayon, textiles, petroleum refining, soap and detergents, cellophane.

Processes: Caustic soda is manufactured primarily from salt in electrolytic cells. A full discussion is included under chlorine.

Waste Problems: See chlorine.

Chlorine

Producer	Capacity 1/
Alcoa	415
Allied	1,100
Diamond	1,850
Dow	7,050
DuPont	180
Ethyl	625
FMC	765
Frontier	415
GAF	475
Goodrich	520
Hooker	1,800

Chlorine (cont.)

Producer	Capacity 1/
IMC	180
Kaiser	500
Monsanto	310
Olin	1,700
Pennsalt	1,000
PPG Industries	2,600
Shell	200
Stauffer	700
Vulcan	300
Wyandotte	1,700
Other	1,300
Total	25,685

1/ tons/day

Production: 1969: 8.6 million tons/year
1974: 12.0 million tons/year

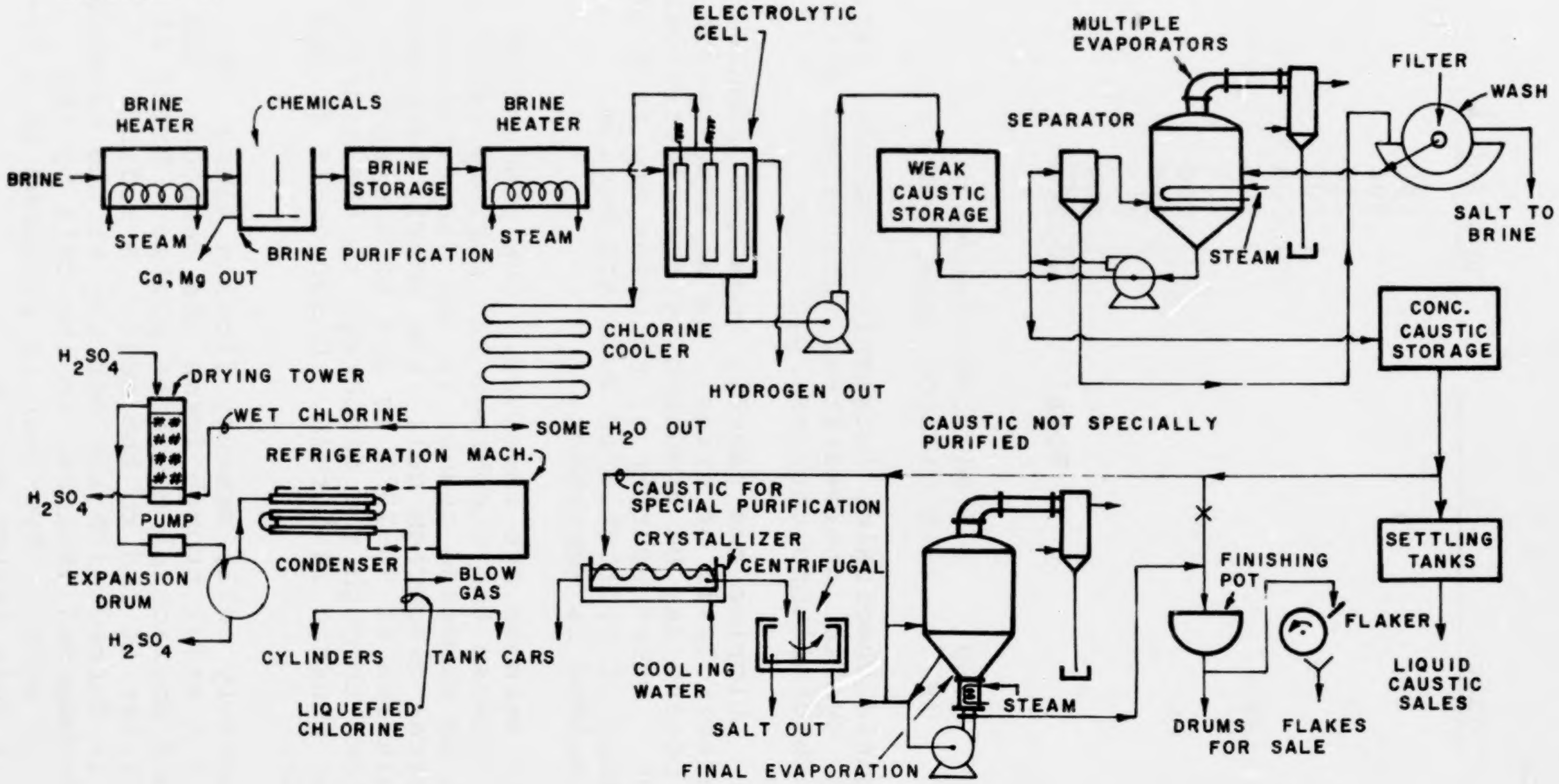
Uses: Organic chemicals, inorganic chemicals, paper industry, cyclic intermediates, sanitation, antifreeze, chlorofluoro carbons, plastics.

Processes: Chlorine and caustic soda are produced by the electrolysis of brine. As an alternative, caustic potash may be produced by the electrolysis of potash. Other sources of chlorine are from the manufacture of hydrochloric acid and sodium. Neither method is important.

Two basic methods are involved. The production is divided between the diaphragm and mercury cells and there is no expected change in the distribution. In a typical diaphragm cell, the nearly saturated brine solution at 60-70°C is fed to the anolyte which flows through the diaphragm to the catholyte where the caustic is formed. Chlorine is formed at the anode.

In the mercury cell, mercury flowing along the bottom of a steel trough forms the cathode. The anodes are horizontal graphite plates. Brine at 290 gms/liter is fed to the cell. A sodium amalgam is formed with the mercury at the cathode and is decomposed external to the cell by the addition of water. Hydrogen is produced as a byproduct of this latter action.

FIGURE 1


BRINE
BRINE HEATER
STEAM
Ca, Mg OUT
CHEMICALS
BRINE PURIFICATION
BRINE STORAGE
BRINE HEATER
STEAM
ELECTROLYTIC CELL
CHLORINE COOLER
HYDROGEN OUT
WEAK CAUSTIC STORAGE
SEPARATOR
MULTIPLE EVAPORATORS
STEAM
FILTER
WASH
SALT TO BRINE
CONC. CAUSTIC STORAGE
H2SO4
DRYING TOWER
WET CHLORINE
SOME H2O OUT
REFRIGERATION MACH.
H2SO4
PUMP
EXPANSION DRUM
CONDENSER
BLOW GAS
H2SO4
CYLINDERS
TANK CARS
LIQUEFIED CHLORINE
CAUSTIC NOT SPECIALLY PURIFIED
CAUSTIC FOR SPECIAL PURIFICATION
CRYSTALLIZER
CENTRIFUGAL
COOLING WATER
SALT OUT
STEAM
FINAL EVAPORATION
FINISHING POT
FLAKER
DRUMS FOR SALE
FLAKES FOR SALE
SETTLING TANKS
LIQUID CAUSTIC SALES

FLOWCHART FOR DIAPHRAGM CAUSTIC SODA AND CHLORINE CELL

This flow chart is selectively reproduced in content and configuration from Figure 13.7 in the book by R. Norris Shreve, *Chemical Process Industries,* Third Edition, New York, Mc Graw - Hill Book Company, 1967, p. 236

Brine purification is necessary to produce a high grade caustic in the diaphragm process. Calcium, iron magnesium and sulfate ions are precipitated. In the diaphragm process, the cell liquor, containing 50% of the sodium chloride, is concentrated.

The salt precipitates and is reused following washing. Special purification of the caustic may be necessary and this usually produces considerable sludge.

It is necessary to dry the chlorine, and this is accomplished by contact with a concentrated sulfuric stream.

The mercury cell produces, without all of the major purification problems, a high purity caustic and chlorine. This eliminates the major waste problems except those arising from chlorine drying.

No significant change is expected in this process.

Waste Problems: The waste problem common to both systems is the waste sulfuric acid stream which amounts to about 1,000,000 gpd/100 tons/day of chlorine. Such a stream (1,000,000 gpd) would contain about 2000 pounds of sulfuric acid and 200 pounds of chlorine. Regeneration of this stream is quite possible by evaporation and steam stripping of the chlorine. This would permit use of the chlorine for sterilization purposes.

Other wastes arise from the discharge of waste brine as a slipstream. This may amount to 1-5% of total brine throughput. Improved brine purification techniques could reduce these practices. The waste brine could be utilized in a small mercury cell to produce chlorine or for the regeneration of ion exchange systems. The waste brine from a mercury cell contains some mercury which requires physical separation for removal. Economics usually justifies removal.

The sludges collected from the purification of brine also create a problem, and current techniques involve land disposal or discharge to a water body. No major processing changes are anticipated.

Soda Ash

Producer	Capacity 1/
Allied, Baton Rouge, La. (S)	785,000
Allied, Green River, Wyo. (N)	550,000
Allied, Syracuse, N.Y. (S)	1,000,000
American Potash, Trona, Calif. (N)	160,000
Diamond Shamrock, Painesville, O. (S)	800,000
Dow, Freeport, Tex. (S)	75,000
FMC, Green River, Wyo. (N)	1,250,000
Olin, Lake Charles, La. (S)	3,750,000
Olin, Saltville, Va. (S)	400,000
PPG, Barberton, O. (S)	600,000
PPG, Corpus Christi, Tex. (S)	240,000
Stauffer, Green River, Wyo. (N)	800,000
Stauffer, Westend, Calif. (N)	160,000
Wyandotte, Wyandotte, Mich. (S)	800,000
Total	7,995,000

1/ tons/year (S) synthetic; (N) natural

Production: 1969: 7,000,000 tons
1974: 9,000,000 tons

Uses: Glass, chemicals, pulp and paper, soap and detergents, aluminum, water treatment.

Processes: About 30% of the current production of soda ash is obtained naturally through the mining of trona (sodium sesquicarbonate). Some amount is recovered through the calcination of natural alkali brines in California. Neither technique produces significant quantities of waste. The mining operation does produce the usual solid waste problems and any brine operation produces a waste brine solution. The location of these areas makes their impact upon the environment relatively insignificant.

The Solvay process uses brine, limestone and coke or gas as the raw material. Brine is purified as previously noted (see chlorine). Ammonia is dissolved in the purified brine and this solution is carbonated with carbon dioxide produce by the decarbonation of limestone by calcining the stone mixed with coke. This produces a moist sodium bicarbonate which is calcined to soda ash. The ammonia is recovered from the filtrate (sodium bicarbonate unit) by addition of quick lime to the system. The ammonia and carbon dioxide are recovered and recycled.

The recovery of ammonia produces a waste stream (1-2000 gals/ton) which contains ammonia (2-4 kgms of $(NH_4)_2SO_4$ per ton of 58% soda ash) and substantial amounts of calcium chloride (0.3 tons/ton of 58% Na_2) and some calcium sulfate and calcium carbonate. While some calcium chloride is recovered by distillation, this practice is not sufficiently prevalent to prevent it from being a major pollution problem.

Since calcination involves dust control, there is the likelihood of a discharge containing a large concentration of suspended solids from a scrubber or where water is used for conveying fly ash.

It is expected that more natural soda ash will be utilized, but no major changes in the manufacture of soda ash by the Solvay process are anticipated.

SIC 2813 (INDUSTRIAL GASES, EXCEPT FOR ORGANIC GASES)

Nitrogen

Producers: The number of nitrogen and oxygen producing plants is quite large and capacities of either individual plants or companies are not available. These plan to be generally located in areas of high user demand.

Major producers are:

Air Products and Chemicals - 20% of market
Airco - 20% of market
Big Three Industrial Gas
Burdett Oxygen
Chemetron - National Cylinder Gas
Union Carbide - Linde Division - 40% of market

Production: 1969: 130,000 million cubic feet
1974: 370,000 million cubic feet

Uses: Chemical and drug production, steel and metal production, electronics, aerospace, cryogenics.

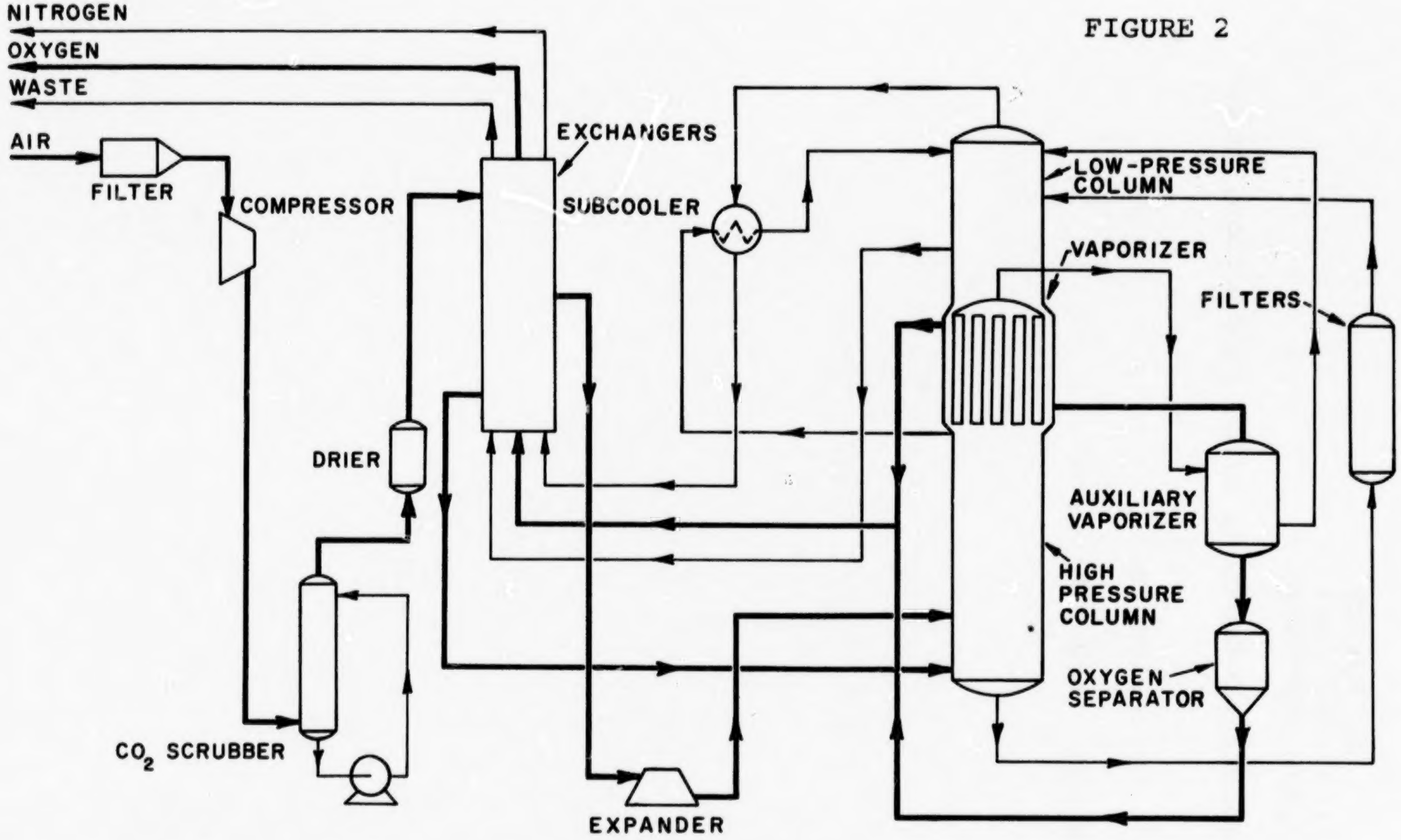
Processes: Both oxygen and nitrogen are produced primarily through the medium pressure liquification and rectification of air. The process can produce a variety of products including high purity oxygen and nitrogen and low purity oxygen. The process naturally has many variations, but it is expected that there will be no substantial changes in the method of production.

Waste Problems: The major problem associated with this process is related to the discharge, with the cooling waters, of waste compressor oils. The quantity of such oils may vary greatly from plant to plant depending on compressor type, size, and age. In-plant control is not only possible, but feasible. This is best done by skimming in the sumps.

Oxygen

Producers: See nitrogen.

FIGURE 2


NITROGEN
OXYGEN
WASTE
AIR
FILTER
COMPRESSOR
EXCHANGERS
SUBCOOLER
DRIER
CO_2 SCRUBBER
EXPANDER
LOW-PRESSURE COLUMN
VAPORIZER
FILTERS
AUXILIARY VAPORIZER
HIGH PRESSURE COLUMN
OXYGEN SEPARATOR

FLOWCHART OF A STANDARD MEDIUM-PRESSURE AIR-SEPARATION PLANT

This flow chart is selectively reproduced in content and configuration from Figure 7.7 in the book by R. Norris Shreve, *Chemical Process Industries*, Third Edition, New York, Mc Graw - Hill Book Company, 1967, p. 109

Production: High Purity (99.5-100%)

1969: 260,000 million cubic feet
1974: 520,000 million cubic feet

Low Purity

1969: 1,900,000 tons
1974: 3,800,000 tons

Uses: Chemical production, steel production, medical.

Processes: See nitrogen.

Waste Problems: See nitrogen.

SIC 2816 (INORGANIC PIGMENTS)

Barites

Producers: Produced by:

Chemical Products Corporation, Cartersville, Ga.
Chicago Copper and Chemical Corporation, Blue Island, Ill.
The Great Western Sugar Corporation, Johnstown, Colo.
Holland-Suco Color Corporation, Huntington, W. Va.
FMC, Modesto, Calif.
Mallinckrodt Chemical, St. Louis, Mo.
Ozark Smelting and Mining, Coffeyville, Kan.
PPG, New Martinsville, W. Va.

Capacities are not available.

Production:		
	1969:	950,000 tons
	1974:	1,300,000 tons

Uses: White pigment.

Processes: Barites is recovered as a mineral which may be converted to a soluble salt, such as the chloride or the sulfide, by thermal reduction. The sulfate is then produced by the addition of a sulfate such as sodium sulfate. The resulting filtrate is a solution of the resulting chloride (usually sodium) on an equivalent mole basis. Thus, the discharge will be a brine solution. No major process change may be expected in the near future and no process improvement is considered likely.

Calcium Carbonate

Producers: Produced by:

Allied, Baton Rouge, La.
Allied, Green River, Wyo.
Allied, Syracuse, N.Y.
American Potash, Trona, Calif.
Diamond Shamrock, Painesville, O.
Dow, Freeport, Tex.
FMC, Green River, Wyo.

Olin, Lake Charles, La.
Olin, Saltville, Va.
PPG, Barberton, O.
PPG, Corpus Christi, Tex.
Stauffer, Green River, Wyo.
Stauffer, Westend, Calif.
Wyandotte, Wyandotte, Mich.

Capacities are not available.

Production: 1969: 180,000 tons (estimated)
1974: 240,000 tons

Uses: Pigment, filler, neutralization, soaps, abrasives, agriculture.

Processes: Whiting is used as a filler and pigment. It is prepared by wet grinding and levigating natural chalk. This process produces a waste which contains large amounts of suspended solids. Artificial whiting arises through the reaction of calcium chloride with sodium carbonate forming a milk of lime suspension. The filtrate from this suspension is high in suspended solids. Use of polyelectrolytes will increase recovery of this product.

Iron Oxide Pigments

Producers: Not available

Production:

1969:	Natural	Brown Iron Oxides	13,000 tons
		Umbers	5,000 tons
		Red Iron Oxides	35,000 tons
		Sienna	1,000 tons
		Yellow Ocher	5,000 tons
		Sienna	1,000 tons
		Subtotal	60,000 tons
	Manufactured	Black	4,000 tons
		Brown	5,000 tons
		Red	32,000 tons
		Yellow	24,000 tons
		Subtotal	65,000 tons
		Total	125,000 tons

1974: 160,000 tons

Processes and Waste Problems: These products are made in dry thermal processes or are produced from natural clays, etc. Therefore, except for waste slurries and equipment washouts, no serious waste problems exist. The discharge of highly colored turbid solutions from clay-mining sites is most serious locally.

Titanium Dioxide

Producer	Capacity 1/
American Potash, Hamilton, Miss. (C)	30,000
Cabot, Ashtabula, O. (C)	20,000
Cyanamid, Piney River, Va. (S)	18,000
Cyanamid, Savannah, Ga. (C,S)	92,000
DuPont, Antioch, Calif. (C)	27,000
DuPont, Baltimore, Md. (S)	40,000
DuPont, Edge Moor, Del. (C,S)	100,000
DuPont, New Johnsonville, Tenn. (C)	68,000
Glidden, Baltimore, Md. (S)	56,000
National Lead, Sayreville, N. J. (C,S)	173,000
National Lead, St. Louis, Mo. (S)	108,000
New Jersey Zinc, Gloucester City, N. J. (S)	46,000
PPG, Natrium, W. Va. (C)	18,000
S. Williams	25,000
Total	821,000

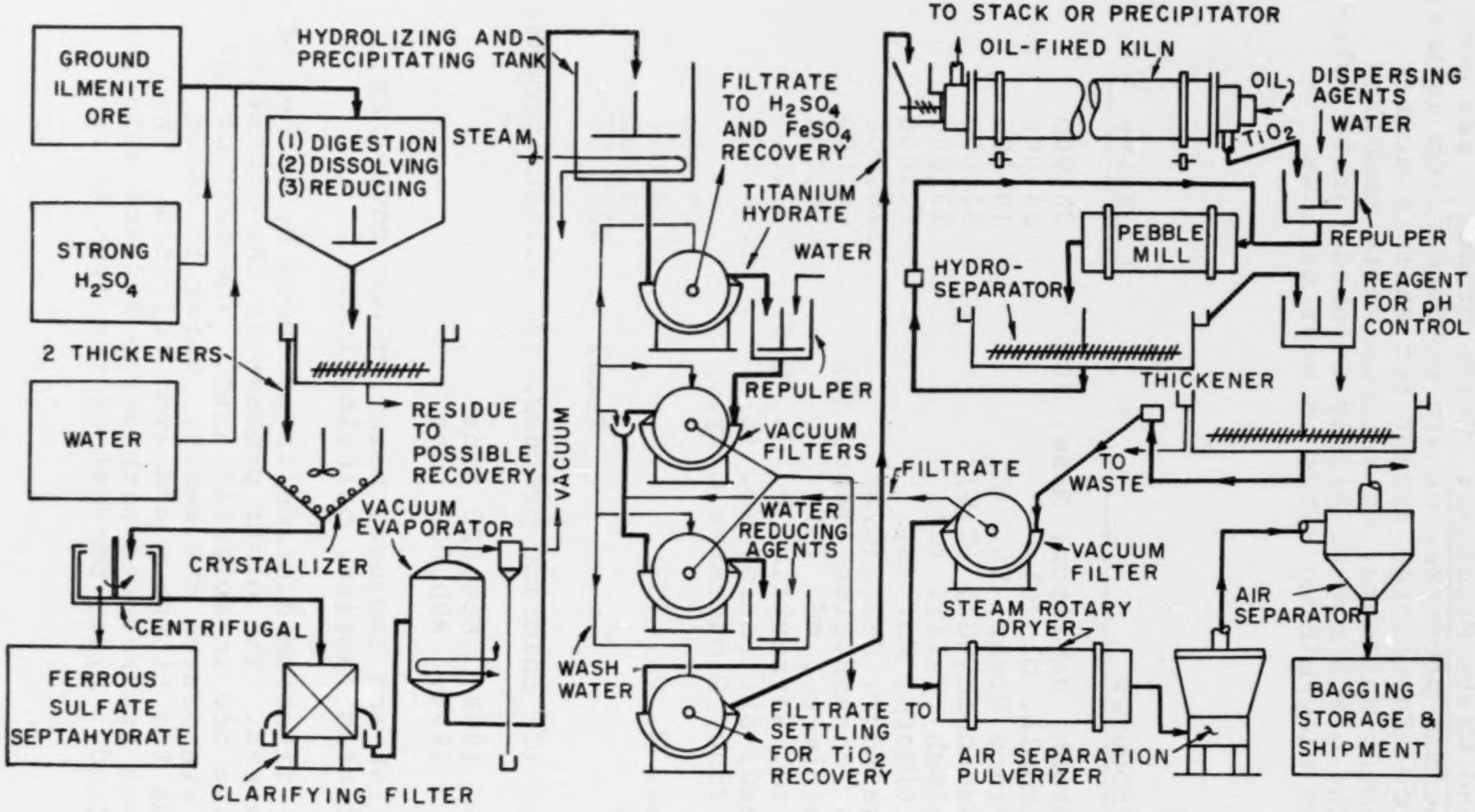
1/ tons/year (C) chloride process; (S) sulfate process

Production: 1969: 650,000 tons
1974: 800,000 tons

Uses: Varnish and lacquer, paint, floor coverings, rubber, coated fabrics, printing ink.

Processes: Titanium dioxide is produced by either of two processes. The older process is the digestion of ilmenite ore in sulfuric acid. The heat of the reaction evaporates the water. Water is added dissolving the titanium and iron sulfates. The ferric ions are reduced with scrap and the solution is clarified. Fifty percent of the iron is re-

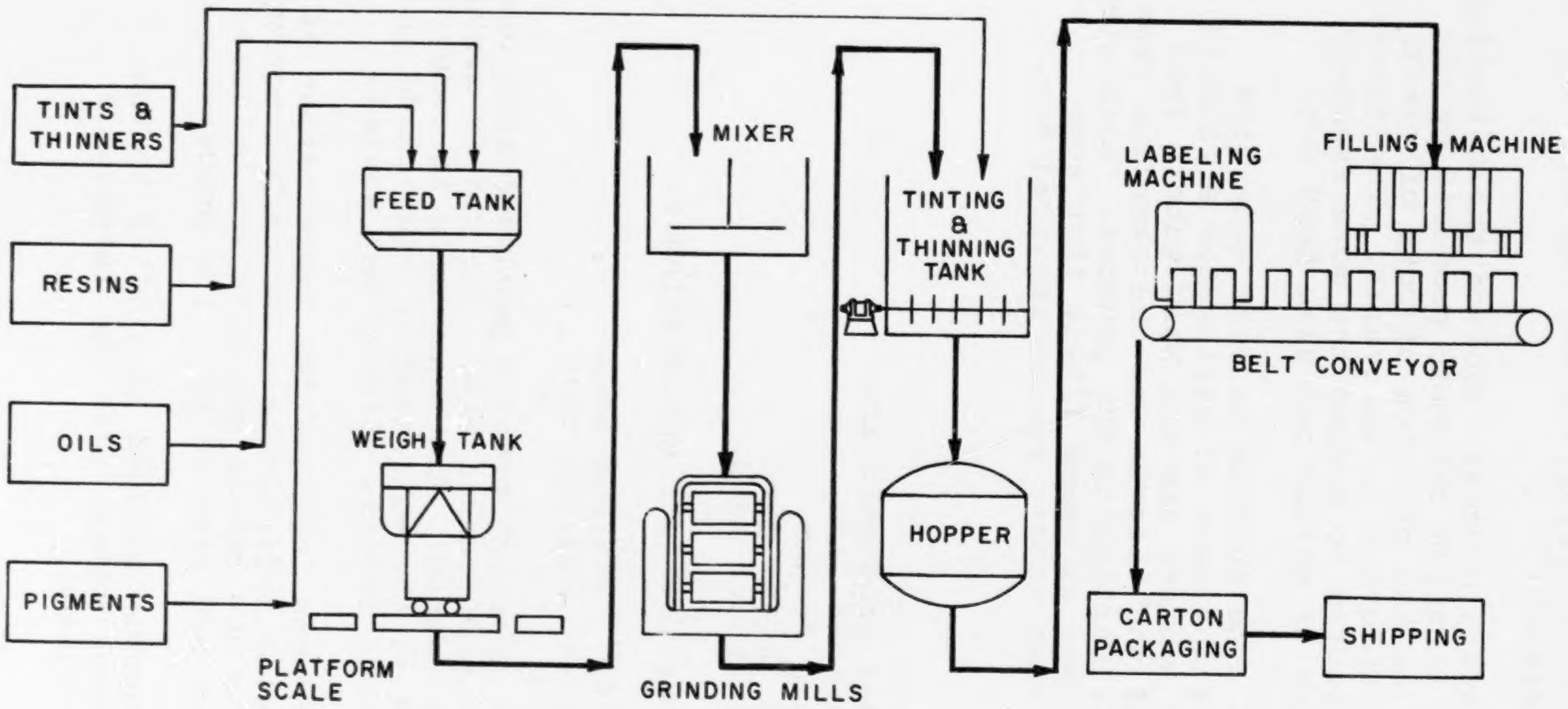
FIGURE 3


GROUND ILMENITE ORE
STRONG H_2SO_4
WATER
2 THICKENERS
(1) DIGESTION
(2) DISSOLVING
(3) REDUCING
HYDROLIZING AND PRECIPITATING TANK
STEAM
RESIDUE TO POSSIBLE RECOVERY
VACUUM
VACUUM EVAPORATOR
CRYSTALLIZER
CENTRIFUGAL
FERROUS SULFATE SEPTAHYDRATE
CLARIFYING FILTER
FILTRATE TO H_2SO_4 AND $FeSO_4$ RECOVERY
TITANIUM HYDRATE
WATER
REPULPER
VACUUM FILTERS
WATER REDUCING AGENTS
WASH WATER
FILTRATE SETTLING FOR TiO_2 RECOVERY
TO STACK OR PRECIPITATOR
OIL-FIRED KILN
OIL
TiO_2
DISPERSING AGENTS
WATER
REPULPER
PEBBLE MILL
HYDRO-SEPARATOR
REAGENT FOR pH CONTROL
THICKENER
FILTRATE
TO WASTE
VACUUM FILTER
STEAM ROTARY DRYER
TO
AIR SEPARATION PULVERIZER
AIR SEPARATOR
BAGGING STORAGE & SHIPMENT

FLOWCHART FOR TITANIUM DIOXIDE

This flow chart is selectively reproduced in content and configuration from Figure 24.9 in the book by R. Norris Shreve, *Chemical Process Industries*, Third Edition, New York, Mc Graw - Hill Book Company, 1967, p. 438

FIGURE 4


TINTS & THINNERS
RESINS
OILS
PIGMENTS
FEED TANK
WEIGH TANK
PLATFORM SCALE
MIXER
GRINDING MILLS
TINTING & THINNING TANK
HOPPER
LABELING MACHINE
FILLING MACHINE
BELT CONVEYOR
CARTON PACKAGING
SHIPPING

FLOWCHART FOR MIXING OF PAINT

This flow chart is selectively reproduced in content and configuration from Figure 24.1 in the book by R. Norris Shreve, *Chemical Process Industries,* Third Edition, New York, Mc Graw - Hill Book Company, 1967, p. 428

moved by crystallization of ferrous sulfate. The titanyl sulfate is hydrolyzed and crystallized and filtered and washed.

The newer chloride process involves the oxidation in a flame of titanium chloride produced by the chlorination, in the presence of coke of rutile ore or slag. Chlorine is recovered. The chloride process is expected to become the more standard one if supplies of rutile and slag hold out.

Waste Problems: The sulfate process generates considerable quantities of wastewater effluents. The principal sources are the wash waters from the washing of the titania and the overflow from the thickeners earlier in the process. Both steps are necessary but it seems likely that some reuse of the wash waters can be provided for.

Zinc Oxide

Producers: Major producers are:
American Zinc
Eagle Picher
New Jersey Zinc
St. Joseph Lead

Capacities are not available.

Production:
1969: 195,000 tons
1974: 220,000 tons

Processes: The American process produces zinc oxide directly from ore franklinite. The ore is mixed with coal and heated. The zinc oxide is reduced to zinc which is then oxidized to zinc oxide in cyclones and bag filters without wet wastes.

The French process involves the vaporization of zinc in a retort with indirect heat and carbon monoxide gas. The zinc and carbon monoxide are oxidized to carbon dioxide and zinc oxide. The process is dry.

The Electrothermic process is similar to the American process except that the furnace is electrically heated.

Aluminum Sulfate

Producers:
Allied
American Cyanamid
DuPont
Essex
Monsanto
Olin
Stauffer

Production:
1969: 1,090,107 tons
1974: 1,250,000 tons

Uses: Water treatment, paper sizing, dye industry.

Production: Aluminum sulfate, while commonly called alum, is not a true alum. True alums are a double sulfate of aluminum or chromium and a monovalent metal or radical.

Aluminum sulfate is made by the reaction of 60 Be' sulfuric acid with bauxite following grinding. The liquor is treated by the addition of barium sulfide to remove iron and is then clarified and solidified. Production means are not likely to change in the near future.

Waste Problems: The major wastes are slurries of solids collected in the thickener decanters. These solids can easily be collected and controlled. No major change in the amount of wastes is expected.

Ammonium Nitrate

AMMONIUM NITRATE PLANTS
UNITED STATES

Company	Location	Capacity-1966 (thousand tons)
Agway, Inc.	Olean, N.Y.	105
Allied Chemical Corp.	Geismar, La.	385
	Hopewell, Va.	400
	Omaha, Nebr.	98
	South Point, O.	235
American Cyanamid Co.	Hannibal, Mo.	140
Apache Powder Co.	Benson, Ariz.	30
Arkla Chemical	Helena, Ark.	150
Armour Agricultural Chemical Company	Cherokee, Ala.	128
	Crystal City, Mo.	111
Calumet Nitrogen Co.	Hammond, Ind.	55
Carolina Nitrogen Co.	Wilmington, N.C.	161
Central Nitrogen Co.	Terre Haute, Ind.	134
Cherokee Nitrogen Co.	Pryor, Okla.	45
Chevron Chemical Co.	Fort Madison, Iowa	70
	Kennewick, Wash.	61
	Richmond, Calif.	55
Columbia Nitrogen Co.	Augusta, Ga.	208
Cominco American, Inc.	Beatrice, Nebr.	200
Commercial Solvents Corporation	Marion, Ill.	...
	Sterlington, La.	148
Escambia Chemical Corporation	Pace, Fla.	100
Farmers Chemical Association	Tyner, Tenn.	180
Farmland Industries	Lawrence, Kans.	208
Fel-Tex, Inc.	Fremont, Nebr.	34
Gulf Oil Corp.	Henderson, Ky.	105
	Pittsburg, Kans.	360
	Vicksburg, Miss.	43
Hawkeye Chemical Co.	Clinton, Iowa	153
Hercules, Inc.	Donora, Pa.	...
	Hercules, Calif.	140
	Louisiana, Mo.	425

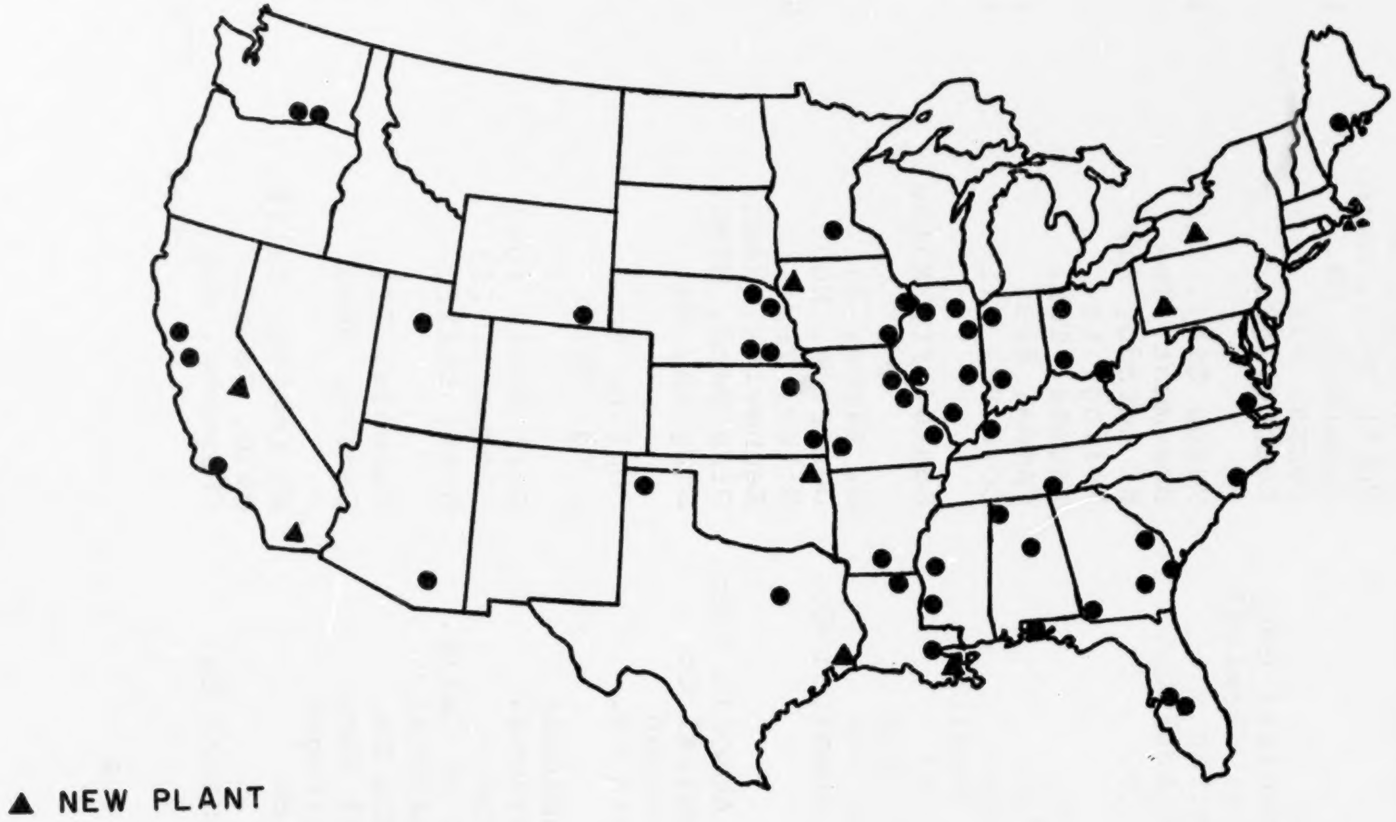
Ammonium Nitrate (cont.)

Company	Location	Capacity-1966 (thousand tons)
Illinois Nitrogen, Inc.	Marseilles, Ill.	132
Kaiser Chemical Co.	Bainbridge, Ga.	50
	North Bend, Ohio	95
	Savannah, Ga.	198
	Tampa, Fla.	54
Ketona Chemical Corp.	Ketona, Ala.	39
Mississippi Chemical Corporation	Yazoo City, Miss.	296
Mobil Chemical Co.	Beaumont, Tex.	200
Monsanto Co.	El Dorado, Ark.	280
	Luling, La.	290
Nipak, Inc.	Kerens, Tex.	56
Nitram, Inc.	Tampa, Fla.	140
Nitrin, Inc.	Cordova, Ill.	110
Northern Chemical Industries	Searsport, Maine	25
Olin Mathieson Chemical Co.	E. Alton, Ill.	50
Phillips Chemical Co.	Beatrice, Nebr.	11
	Etter, Tex.	240
	Kennewick, Wash.	20
St. Paul Ammonia Corp.	Pine Bend, Minn.	88
Smith Chemical Co.	Douglas, Ga.	...
Solar Nitrogen Chemicals Co.	Joplin, Mo.	110
	Lima, Ohio	75
Terra Chemicals International	Port Neal, Iowa	145
Texaco, Inc.	Lockport, Ill.	95
Union Oil of Calif.	Brea, Calif.	60
U.S. Industrial Chemicals Co.	Tuscola, Ill.	88
U.S. Steel Corp.	Geneva, Utah	90
Valley Nitrogen Producers	El Centro, Calif.	88
	Helm, Calif.	35
Wycon Chemical Co.	Cheyenne, Wyo.	37
	Total	7,874

Source: TVA

AMMONIUM NITRATE PLANT LOCATIONS

FIGURE 5



Production: 1969: 5,200,000 tons
1974: 6,300,000 tons

Uses: Fertilizer, explosives.

Processes: While some ammonium nitrate is manufactured by the old batch method, the vast majority is manufactured by one of a variety of continuous processes. All processes involve the direct contact of preheated ammonia and nitric acid, separation of the gaseous water, and prilling or flaking by melting. While various modifications are continuously being brought into use, no basic changes are expected.

Waste Problems: Washdown produces substantial amounts of nitrogen rich wastewaters. Additional amounts are associated with scrubber blowdowns and from cooling water. Improved plant maintenance would assist in controlling this problem.

Ammonium Sulfate

Producers: A detailed list is not available because of the large number of by-product producers, but producers include:

- Alabama By-Products
- Allied Chemical
- American Cyanamid
- Bethlehem Steel
- C. F. & I Steel
- Chevron
- Columbia Nitrogen
- DuPont
- Graver
- Inland Steel
- Interlake Steel
- Olin
- Phillips
- Shell
- Simplot
- Sinclair
- Sunray
- U. S. Pipe
- U. S. Steel

Production: 1969: 2,715,000 tons
1974: 3,000,000 tons

Uses: Fertilizer

Processes: About 35% of the production is associated with the direct reaction of ammonium salts such as the carbonate with sulfuric acid. Some is made by the use of gypsum in place of the sulfuric acid. Major discharges involve solid slurries of by-product materials.

Major amounts of ammonium sulfate are made during the recovery of ammonia from coke oven gas. About 40% of the total production is involved with the actual recovery of by-product ammonia from a variety of other processes. A plant in California is being built based on the reaction of gypsum and ammonia. To summarize, most of the ammonium sulfate produced in this country is a result of attempts to control atmospheric pollution. No change in production pattern is expected to occur.

Waste Problems: As indicated above, no major waste problem exists.

Calcium Carbide

Producer	Capacity [1/]
Airco, Calvert City, Ky.	300,000
Airco, Keokuk, Iowa	36,000
Airco, Louisville, Ky.	150,000
Midwest Carbide, Keokuk, Iowa	50,000
Midwest Carbide, Pryor, Okla.	30,000
Pacific Carbide, Portland, Ore.	20,000
Union Carbide, Ashtabula, Ohio	228,000
Union Carbide, Niagara Falls, N. Y.	210,000
Union Carbide, Portland, Ore.	32,000
Union Carbide, Sheffield, Ala.	60,000
Total	1,116,000

[1/] tons/year

Production: 1969: 920,000 tons
1974: 900,000 tons

Uses: Production of acetylene.

Processes: Calcium carbide is prepared from quicklime and carbon (usually coke, petroleum coke or anthracite) at 2000-2200°C in a furnace related to the familiar arc furnace. No major process change is expected but the use of carbide-based acetylene is expected to be reduced in the future.

Waste Problems: Since the process is not a wet process, the only major discharges are associated with wastewaters used to scrub furnace and kiln effluents.

Hydrochloric Acid

Producers: Most HCl is produced as a by-product from the production of carbon tetrachloride and other chlorinated hydrocarbons, PVC, ethylene oxide, and phenol. (See "Projected Wastewater Treatment Costs in the Organic Chemicals Industry," Department of the Interior.) Major producers of anhydrous HCl are:

Detrex
Diamond Shamrock
Dow
Hooker
Montrose
Morton
Shell
Stauffer
Vulcan

Major producers of aqueous HCl are:

Allied
Arkla
Baker
Cabot
Detrex
Diamond Shamrock
Dow
DuPont
GAF
Hooker
Mobay
Monsanto
Mont
Morton
Olin
PPG
Pearsall
Pennsalt
PCA
Reichhold
Shell
Stauffer
Velsicol
Vulcan
Wyandotte

Production: 1969: 1,800,000 tons
1974: 2,200,000 tons

Uses: Oil well activation, chemical production, steel pickling, monosodium glutamate and starch hydrolysis, metal cleaning.

Processes: The major portion of HCl currently produced (85%) is a by-product of the chlorination of hydrocarbons. However, it is expected that the amount of by-product HCl available will be greatly decreased in the future for several reasons. These include:

1. The practice of oxychlorination is increasing rapidly and this, in a balanced system, can eliminate the presence of waste HCl.
2. Most vinyl chloride plants employ oxychlorination and do not produce major amounts of waste acid.
3. A new process, based on a modification of the old Deacon process, as developed by Kellogg, is expected to produce large amounts of chlorine (note impact on chlorine under #2812) and consume substantial amounts of by-product acid.

There are sufficient amounts of waste acids available so that the short term supply will not be a problem.

Three other sources of supply are as follows:

1. Direct burning of chlorine in a small excess of hydrogen. This is followed by the adsorption of HCl in water, followed by stripping to produce a high purity HCl.
2. The reaction of salt and sulfuric acid in a high temperature furnace. Sodium sulfate is formed as a by-product. Adsorption of the acid in water takes place with removal of salt and acid in a coke tower.
3. A Hargreaves-type operation which involves the reaction of salt, sulfur dioxide, oxygen and water to form sodium sulfate and acid. (This process is used by only one plant.)

Waste Problems: In the salt acid reaction, the washing out of the coke tower produces a waste stream of acid and salt. Improved furnace design would cut down on the amount of carryover.

In the salt-acid process, as in the Hargreaves reaction, a stream of weak sulfuric amounting to 50-90 lbs/ton 20° Be' hydrochloric acid is produced.

Weak hydrochloric acid is also wasted from the system.

Hydrofluoric Acid

Producer	Capacity 1/
Alcoa, Point Comfort, Tex.	25,000
Allied, Baton Rouge, La.	15,000
Allied, Geismar, La.	15,000
Allied, Nitro, W. Va.	20,000
Allied, North Claymont, Del.	25,000
Allied, Port Chicago, Calif.	12,000
DuPont, Deepwater Point, N. J.	15,000
DuPont, Strang, Tex.	50,000
Essex, Paulsboro, N. J.	11,000
Harshaw, Cleveland, Ohio	10,000
Kaiser, Gramercy, La.	15,000
Olin, Joliet, Ill.	12,000
Pennsalt, Calvert City, Ky.	18,000
Reynolds, Bauxite, Ark.	40,000
Stauffer, Houston, Tex.	18,000
Total	301,000

1/ tons/year

Production: 1969: 310,000 tons
1974: 420,000 tons

Uses: Fluorocarbons, aluminum, petroleum alkylation, stainless steel pickling, AEC work.

Processes: HF is prepared by heating, in kilns, the ore-fluorspar (CaF_2) with sulfuric acid. The gaseous HF is either absorbed in water or liquified, employing refrigeration to obtain the anhydrous product.

Waste Problems: Not significant except in washout where fluoride concentrations can be a serious problem.

Hydrogen Peroxide

Producer	Capacity [1]
Allied, Syracuse, N. Y.	4,000
DuPont, Memphis, Tenn.	25,000
FMC, Buffalo, N. Y.	6,000
FMC, South Charleston, W. Va.	8,000
FMC, Vancouver, Wash.	6,000
Pennsalt, Wyandotte, Mich.	1,750
Pittsburgh Plate, Barberton, Ohio	3,750
Shell, Norco, La.	17,000
Total	71,500

[1] tons/year

Production: 1969: 70,000 tons
1974: 100,000 tons

Uses: Textiles, paper and pulp, plasticizers, chemicals.

Processes: Hydrogen peroxide is manufactured by one electrolytic and two organic oxidation processes. Sulfuric acid is electrolyzed to peracid ($H_2S_2O_8$) which hydrolyzes to sulfuric acid and peroxide.

The organic processes center on 2-ethylanthraquinone which is oxidized to produce peroxide and recycleable quinone and isopropyl alcohol. The latter are oxidized at modest temperatures and pressures to peroxide and acetone.

Waste Problems: The electrolytic process produces a stream of dilute sulfuric acid. The organic based processes will probably produce a waste stream from the distillation column.

Lime

Producers: There are some 210 lime producing plants located wherever there are significant limestone deposits. This list is too exhaustive for display here. Refer to "Minerals Yearbook," U. S. Bureau of Mines, for a complete listing.

Production: 1969: Quicklime - 14,000,000 tons
Hydrated - 3,000,000 tons
1974: Total - 19,000,000 tons

Uses: Agriculture, chemical manufacture, pulp manufacture, tanning, steel and cement manufacture, water treatment, soap manufacturing, construction.

Processes: Thermal decarbonation of limestone or calcium carbonate sludge usually in a shaft kiln or a rotary kiln but also in a fluidized bed kiln.

Waste Problems: These generally arise if solids capture is by wet scrubbing. Conversion to a dry capture system such as bag filters would eliminate the problem.

Nitric Acid

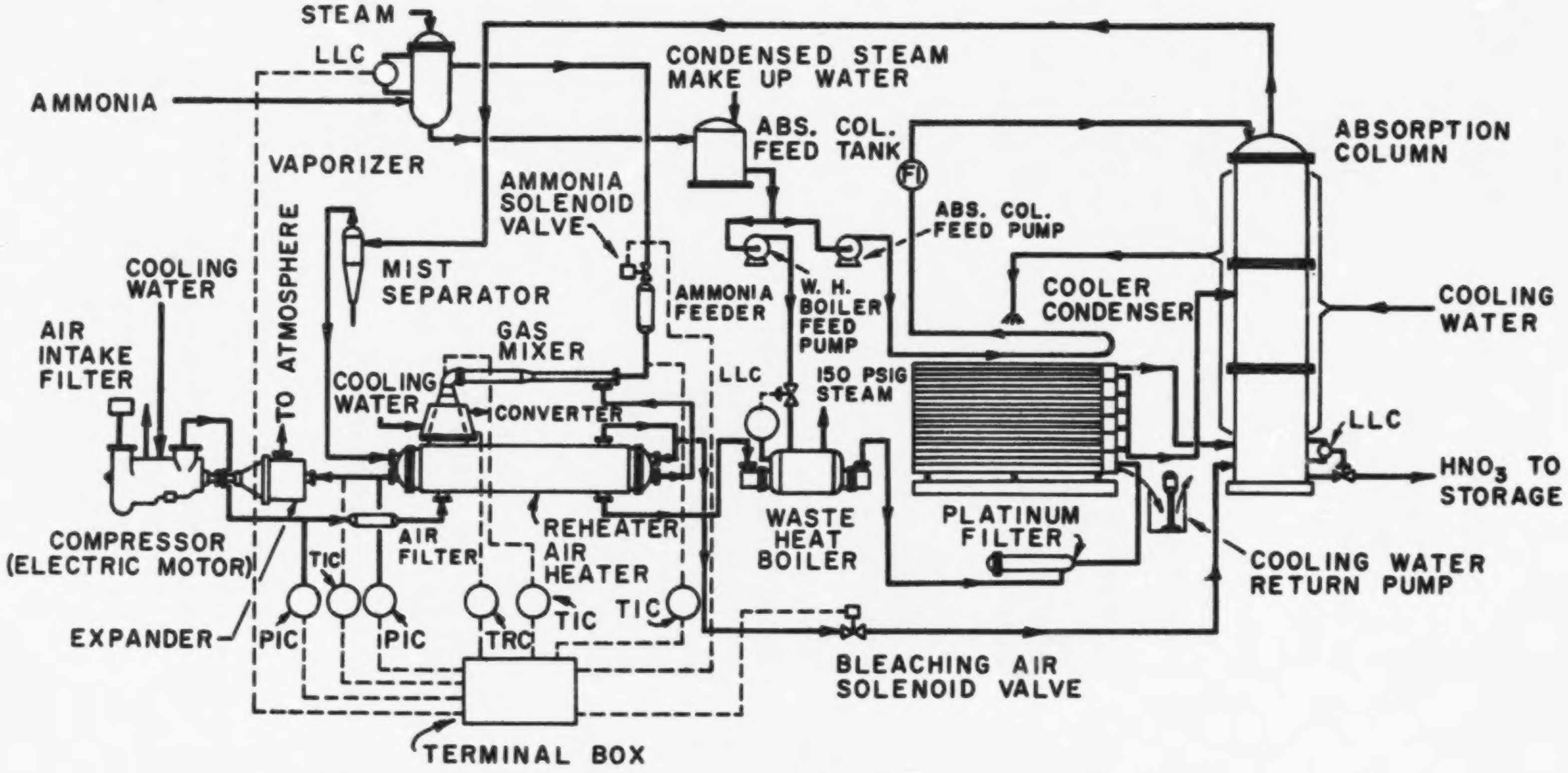
Producers:

Company	Plant Location	Estimated capacity ('68) (1,000 tons/year)	
		Plant	Co. Total
Agway	Olean, N.Y.	60	60
Allied	Buffalo, N.Y.	25	
	Geismar, La.	200	
	Hopewell, Va.	250	
	La Platte, Nebr.	90	
	Newell, Pa.	60	
	South Point, O.	240	865
American Cyanamid	Bound Brook, N.J.	25	
	Hannibal, Mo.	110	
	Willow Island, W. Va.	27	162
Arkla	Helena, Ark.	90	90
Armour	Cherokee, Ala.	110	
	Crystal City, Mo.	100	210
Atlas	Joplin, Mo.	122	
	Tamaqua, Pa.	24	146
Celanese	Bay City, Tex.	77	77
Central Farmers	Fremont, Nebr.	31	31
Central Nitrogen	Terre Haute, Ind.	133	133

Nitric Acid (cont.)

Company	Plant Location	Estimated capacity ('68) (1,000 tons/year)	
		Plant	Co. Total
Cherokee	Prior, Okla.	65	65
Chevron	Ft. Madison, La.	94	
	Kennewick, Wash.	130	
	Richmond, Calif.	85	
			309
Collier	Brea, Calif.	47	47
Columbia Nitrogen	Augusta, Ga.	162	162
Cominco	Beatrice, Nebr.	135	135
Commercial Solvents	Marion, Ill.	50	
	Sterlington, La.	163	
			213
Cooperative Farm Chems.	Lawrence, Kans.	485	485
DuPont	Barksdale, Wis.	20	
	Belle, W. Va.	82	
	Birmingham, Ala.	20	
	DuPont, Wash.	20	
	Gibbstown, N.J.	350	
	Louviers, Colo.	15	
	Old Hickory, Tenn.	44	
	Orange, Tex.	180	
	Victoria, Tex.	120	
	Seneca, Ill.	215	
	Wabash, Ind.	150	1,216
El Paso	Odessa, Tex.	63	63
Escambia	Pensacola, Fla.	90	90
Farmers' Chemical	Tyner, Tenn.	170	170
Grace	Wilmington, N. C.	164	164
Gulf	Henderson, Ky.	85	
	Pittsburg, Kans.	281	
	Vicksburg, Miss.	85	
			451
Hawkeye	Clinton, La.	125	125
Hercules	Bessemer, Ala.	20	
	Hercules, Calif.	65	
	Kenvil, N.J.	16	
	Louisiana, Mo.	400	
	Parling, N.J.	53	
	Donora, Pa.	120	
			674
Illinois Nitrogen	Marseilles, Ill.	120	120

FIGURE 6


STEAM
LLC
AMMONIA
CONDENSED STEAM
MAKE UP WATER
ABS. COL.
FEED TANK
FI
ABSORPTION
COLUMN
VAPORIZER
AMMONIA
SOLENOID
VALVE
ABS. COL.
FEED PUMP
COOLING
WATER
TO ATMOSPHERE
MIST
SEPARATOR
AMMONIA
FEEDER
W. H.
BOILER
FEED
PUMP
COOLER
CONDENSER
COOLING
WATER
AIR
INTAKE
FILTER
GAS
MIXER
LLC
150 PSIG
STEAM
COOLING
WATER
CONVERTER
LLC
HNO_3 TO
STORAGE
WASTE
HEAT
BOILER
PLATINUM
FILTER
COMPRESSOR
(ELECTRIC MOTOR)
TIC
AIR
FILTER
REHEATER
AIR
HEATER
COOLING WATER
RETURN PUMP
EXPANDER
PIC
PIC
TRC
TIC
TIC
BLEACHING AIR
SOLENOID VALVE
TERMINAL BOX

FLOWCHART FOR 60% NITRIC ACID FROM AMMONIA

This flow chart is selectively reproduced in content and configuration from Figure 18.9 in the book by R. Norris Shreve, *Chemical Process Industries*, Third Edition, New York, Mc Graw - Hill Book Company, 1967, p. 318

Nitric Acid (cont.)

Company	Plant Location	Estimated capacity ('68) (1,000 tons/year)	
		Plant	Co. Total
Kaiser	Bainbridge, Ga.	47	
	North Bend, O.	84	
	Savannah, Ga.	162	
	Tampa, Fla.	42	
			335
Ketona	Ketona, Ala.	36	36
Miscoa	Yazoo City, Miss.	388	388
Mobay	New Martinsville, W. Va.	50	50
Mobil	Beaumont, Tex.	154	154
Monsanto	El Dorado, Ark.	275	
	Luling, La.	270	
	Pensacola, Fla.	258	
			803
Nipak	Kerens, Tex.	50	50
Nitram	Tampa, Fla.	120	120
Nitrin	Cordova, Ill.	95	95
Northern Chemical Industries	Searsport, Maine	25	25
Olin Mathieson	Lake Charles, La.	95	95
Phillips Chemical	Kennewick, Wash.	43	
	Beatrice, Nebr.	9	
	Etter, Tex.	164	
	Pasadena, Tex.	13	
St. Paul Ammonia	Pine Bend, Minn.	100	100

Production: 1969: 6,140,000 tons
1974: 7,000,000 tons

Uses: Fertilizers, chemicals, photoengravings, explosives.

Processes: Nitric acid is produced by the catalytic air oxidation of ammonia. Nitric oxide is absorbed in water and oxidized. Higher strength nitric acid is produced by breaking the azeotrope with either sulfuric acid or magnesium nitrate. No significant changes are expected in the production of nitric acid.

Waste Problems: Major problems are associated with cooling water blowdown and area washdown which may contain troublesome amounts of nitric acid.

Phosphoric Acid

Producers	Location	Capacity (tons 100% P_2O_5/yr)
Allied Chemical	E. St. Louis, Ill.	36,200
	N. Claymont, Del.	36,200
	Geismar, La.	159,300
American Agricultural Chem.	Pierce, La.	216,000
American Cyanamid	Brewster, Fla.	148,800
American Potash	Trona, Calif.	Not Available
Arkla Chemical	Helena, Ark.	50,000
Armour Agricultural	Bartow, Fla.	85,000
	Ft. Meade, Fla.	188,000
Borden	Piney Point, Fla.	165,000
	Streator, Ill.	24,000
	Texas City, Tex.	60,000
Bunker Hill	Kellogg, Ida.	24,500
Central Phosphates	Plant City, Fla.	200,000
Coastal Chemical	Pascagoula, Miss.	175,900
Consumers Cooperative	Pierce, Fla.	200,000
Des Plaines Chemical	Morris, Ill.	50,000
El Paso Natural Gas	Conda, Ida.	100,000
Farmers Chemical	Joplin, Mo.	55,000
Freeport Sulfur	Uncle Sam, La.	540,000
W. R. Grace	Bartow, Fla.	415,000
	Joplin, Mo.	35,000
National Phosphate	Taft, La.	207,000
	Marseilles, Ill.	103,500
IMC	Bonnie, Fla.	500,000
New Jersey Zinc	Depue, Ill.	150,000
Nipak	Tulsa, Okla.	21,000
NW Cooperative Mills	Pine Bend, Minn.	32,000

Phosphoric Acid (cont.)

Producers	Location	Capacity (tons 100% P_2O_5/yr)
Occidental Petroleum	Hamilton Co., Fla.	207,000
Best Fertilizer	Lathrop, Calif.	17,300
Olin Mathieson	Joliet, Ill.	127,000
	Pasadena, Tex.	217,500
Phosphate Chemicals	Pasadena, Tex.	50,000
F. S. Royster Guano	Mulberry, Fla.	130,000
J. R. Simplot	Pocatello, Ida.	265,000
Mobil Chemical	Nichols, Fla.	125,000
Western Phosphates	Garfield, Utah	70,000
Swift	Agricola, Fla.	126,300
Tennessee Corp.	E. Tampa, Fla.	490,000
TGS	Aurora, N. C.	347,000
U.S. Industrial Chemicals	Tuscola, Ill.	40,000
Valley Nitrogen	Helm, Calif.	50,000
Western States Chem.	Point Chicago, Calif.	90,000
	Total	5,807,500

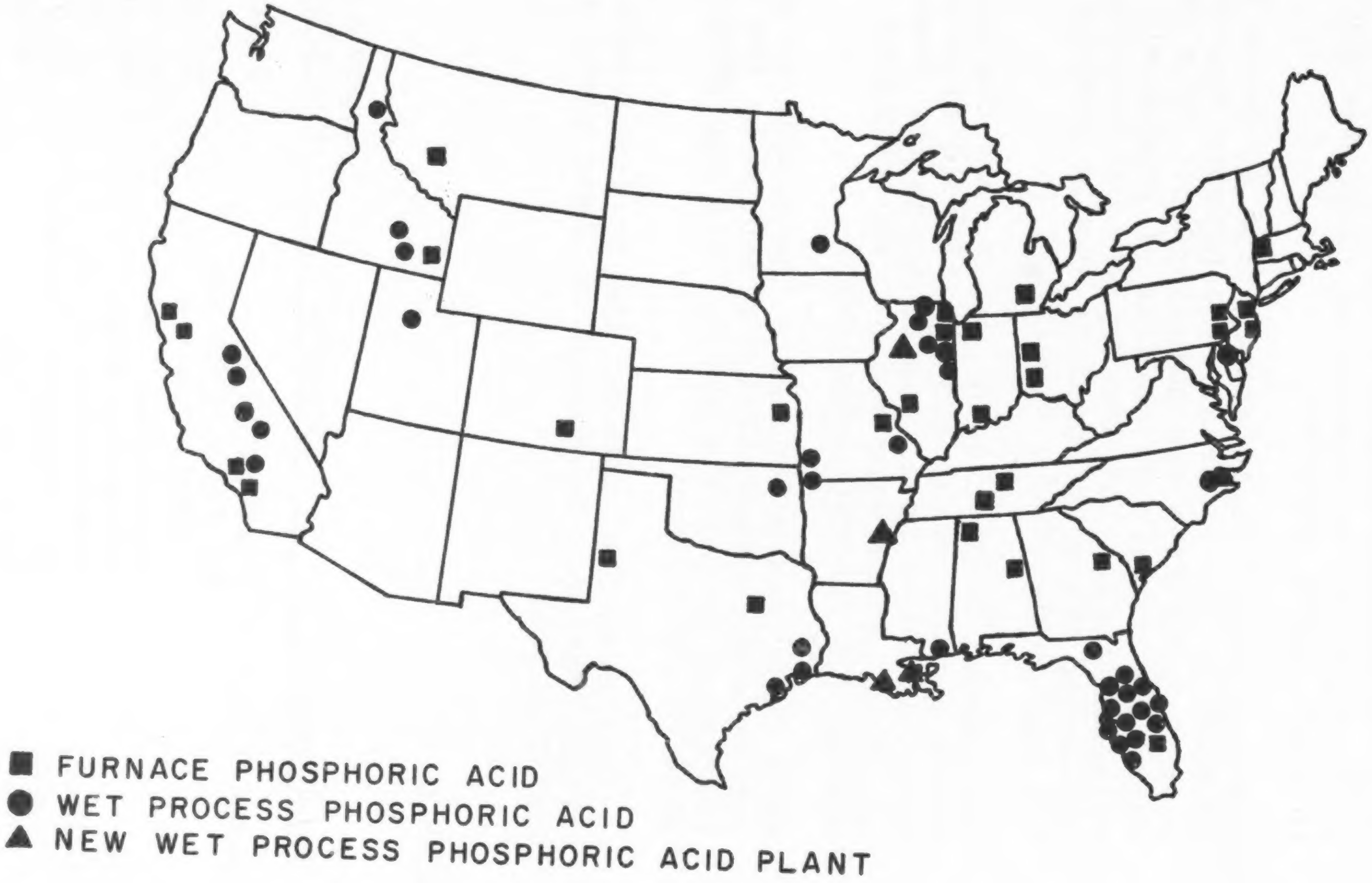
Production: 1969: 4,926,000 tons (100% P_2O_5)
1974: 5,900,000 tons (100% P_2O_5)

Uses: Fertilizer, detergents, food.

Processes: Phosphoric acid is produced by two methods. One method involves the hydrolysis of phosphorous and will be discussed under phosphorous. The most common approach is responsible for some 80% of the total production; this is from the acidulation of phosphate rock. Usually the acidulation involves the use of sulfuric acid. The acid is concentrated while the by-product, gypsum, is filtered and washed.

PHOSPHORIC ACID PLANT LOCATIONS

FIGURE 7


■ FURNACE PHOSPHORIC ACID
● WET PROCESS PHOSPHORIC ACID
▲ NEW WET PROCESS PHOSPHORIC ACID PLANT

Alternative routes involve the use of nitric or hydrochloric in place of sulfuric. This approach is not likely to make any impact on acid production.

The swing towards production of a more usable by-product in the form of the hemihydrate will have a major impact upon waste treatment. On the other hand, increasing pressure relative to air pollution will increase the removal of fluorides and thereby increase waste streams.

Waste Problems: Waste arises from at least four sources in the process. The primary source is the waste gypsum from the acidulation. This semi-solid waste may contain quantities of phosphoric and sulfuric acid. The development of techniques for utilizing the waste product should greatly reduce the magnitude of the problem.

The second source is the water from the scrubbers which contain large amounts of acid fluorides. By-product use would appear to be the answer here, as well. Increasing amounts are utilized as a source for fluoride chemicals.

This third waste source is the sludge of aluminum and iron phosphate sludge produced by the post precipitation of the acid. This may amount to 1-5% of production.

A fourth source involves the tailings from the rock beneficiation. No change in these waste sources is anticipated.

Phosphorus

Producers	Location	Capacity (tons/year)
Continental Oil	Pierce, Fla.	30,000
	El Paso, Georgetown, Ida.	21,000
FMC	Pocatello, Idaho	142,000
Hooker	Columbia, Tenn.	68,500
Mobil (V-C)	Charleston, S. C.	10,000
Mobil (V-C)	Mt. Pleasant, Tenn.	20,000
Mobil (V-C)	Nichols, Fla.	6,000

Phosphorus (cont.)

Producers	Location	Capacity (tons/year)
Monsanto	Columbia, Tenn.	110,000
Monsanto	Soda Springs, Idaho	120,000
Stauffer	Mt. Pleasant, Tenn.	80,000
Stauffer	Silver Bow, Mont.	30,000
Stauffer	Tarpon Springs, Fla.	12,500
TVA	Wilson Dam, Ala.	110,000
	Total	760,000

Production: 1969: 610,000 tons
1974: 740,000 tons

Uses: Sodium tripolyphosphate, phosphoric acid, other sodium phosphates, calcium phosphates, tetrapotassium pyrophosphate, sodium metaphosphate.

Processes: Phosphate rock is mixed with sand and coke, sintered and introduced into an electric furnace. After heating at elevated temperature, slag and ferrophosphorous is drawn off. Phosphorous vapor is drawn off and condensed. Phosphorous is oxidized to P_2O_5 which is cooled and hydrated, filtered and purified.

Waste Problems: A stream containing a significant amount of phosphorous (1% of production) is known as "phossy" water. The phosphorous may be settled, thickened and recycled. The filtration of the acid also produces a waste sludge of acid which causes a disposal problem. No major processing changes are anticipated.

TKPP

Producer	Location	Capacity 1/
FMC	Carteret, N. J.	10,000
FMC	Newark, Calif.	2,500
Hooker	Jeffersonville, Ind.	5,000
Mobil (V-C)	Fernald, Ohio	12,000
Monsanto	Carondelet, Mo.	15,000

TKPP (cont.)

Producer	Location	Capacity 1/
Olin	Joliet, Ill.	5,000
Stauffer	Chicago Heights, Ill.	7,500
Stauffer	South Gate, Calif.	2,500
	Total	59,500

1/ tons/year

Production: 1969: 48,500 tons
1974: 60,000 tons

Uses: Liquid detergent builder.

Processes: TKPP is prepared by the reaction of phosphoric acid and potassium carbonate to produce dipotassium-phosphate which is calcined to TKPP.

Waste Problems: Not significant.

Sodium Metal

Producers	Location	Capacity 1/
DuPont	Memphis, Tenn.	70
	Niagara Falls, N.Y.	84
Ethyl	Baton Rouge, La.	90
	Houston, Tex.	60
National Distillers	Ashtabula, Ohio	56
	Total	360

1/ million lbs/year

Production: 1969: 165,000 tons
1974: 200,000 tons

Uses: Tetraethyl and tetramethyl lead, potassium, sodium peroxide, sodium cyanide.

Processes: Electrolysis of fused sodium chloride. The crude sodium is filtered at 105-110°C.

Waste Problems: Since the process is run dry, waste problems are limited to washouts, spills and filter cake discharge.

Sodium Bicarbonate

Producer	Location	Capacity 1/
Church & Dwight	Syracuse, N. Y.	100,000
Church & Dwight	Green River, Wyo.	40,000
Diamond	Painesville, Ohio	28,000
Olin	Saltville, Va.	23,000
PPG	Barberton, Ohio	40,000
Wyandotte	Wyandotte, Mich.	30,000
	Total	261,000

1/ tons/year

Production: 1969: 205,000 tons
1974: 235,000 tons

Uses: Food, chemicals, drugs, fire extinguishant, soap and detergents, leather, textile, and paper.

Processes: Sodium bicarbonate is not made by refining the crude sodium bicarbonate from the Solvay process. A saturated solution of soda ash (natural or synthetic) is prepared and is carbonated with CO_2 in a tower. The suspension is filtered, washed, centrifuged and dried.

Waste Problems: Major problem is the blowdown of the filter cake and filter cake washups. No significant process changes are expected and no change in the nature of pollutional problems seems likely.

Sodium Bichromate

Producer	Location	Capacity 1/
Allied	Baltimore, Md.	90,000
Diamond Shamrock	Kearny, N.J.	15,000
Diamond Shamrock	Painesville, Ohio	50,000
Hercules	Glen Falls, N.Y.	16,000
Pittsburgh Plate	Corpus Christi, Tex.	35,000
	Total	206,000

1/ tons/year

Production: 1969: 150,000 tons
1974: 165,000 tons

Uses: Pigments, leather tanning, chromic acid, metal treatment, textiles and dyes.

Processes: The raw material is a chromium iron oxide containing about 50% Cr_2O_3. The ore is ground to 200 mesh, mixed with limestone and soda ash and heated to 2200°F in a strongly oxidizing atmosphere. The mass is leached with hot water to remove the soluble sodium chromate. The solution is acidified to convert the chromate to dichromate. The sodium sulfate crystallizes out and the solution is sent to crystallizers to recover the dichromate. No process changes are expected.

Waste Problems: The solution coming off the crystallizers contains about 0.1 ton of Na_2SO_4 per ton of sodium dichromate and minor amounts of sodium dichromate and chromate. Use of ion exchange and other concentrating systems could permit recovery from this system.

Sodium Chloride

Producers	Capacity 1/
Morton	6
International	4
Diamond Crystal	2.5
Leslie	1.5
Other salt companies	5
Total noncaptive capacity	19
Captive to chemical companies	22
Total salt and brine	41

1/ million tons/year

Production: 1969: 43,000,000 tons
1974: 57,000,000 tons

Uses: Production of chlorine, caustic, soda ash, other chemicals, highway use, food, feed, water conditioning.

Processes: Salt is obtained in three fashions: one by solar evaporation of sea water or western lake brines; another from well brine and a third by the mining of rock salt. It is necessary to remove calcium and magnesium chlorides, usually by undertaking evaporative concentration followed by filtration of the precipitated salts of Mg and Ca. The process may undergo some modification but major changes are not likely.

Waste Problems: Wastewater results from two sources. One is the deposits of calcium and magnesium salts which are removed in the process. This slurry can amount to 3-5% of the total process flow.

The second source is the slip stream removed to control impurities in any recycling system such as the Alberger method. Use of a concentrating or an ion control system may be effective in controlling this problem internally.

Sodium Silicate

Producer	Capacity 1/
Allied	105,000
Amerace	25,000
Chemical Products	10,000
Diamond	230,000
DuPont	150,000
Grace	65,000
Philadelphia Quartz	225,000
Philadelphia Quartz (Calif.)	35,000
Pittsburgh Plate	60,000
Proctor & Gamble	20,000
Twin Chemical	15,000
Total	940,000

1/ tons/year

Production: 1969: 640,000 tons
1974: 750,000 tons

Uses: Catalysts and silica gels, soaps and detergents, boxboard adhesives, pigments, water, paper and ore treatment.

Processes: Sodium silicates are prepared by fusing sodium carbonate and silica sand in a glass melting furnace at about 1300°C. If the product is to be sold as a solution, it is dissolved by steam injection. No process change is anticipated.

Waste Problems: None except washdown.

Sodium Sulfite

Producer	Location	Capacity 1/
Allied	El Segundo, Calif.	5,000
Allied	N. Claymont, Del.	10,000
Koppers	Petrolia, Pa.	25,000
Monsanto	Monsanto, Ill.	62,500
Reichhold	Tuscaloosa, Ala.	145,000
Stauffer	South Gate, Calif.	3,000
	Total	250,500

1/ tons/year

Production: 1969: 230,000 tons
1974: 240,000 tons

Processes: Direct contact between SO_2 and soda ash followed by boiling off of CO_2. Sesqihydrate is precipitated. Another source is as a by-product in the preparation of phenol by the fusion of sodium benzene sulfonate with caustic (See "Waste Water Treatment Costs in the Organic Chemical Industry," U. S. Department of the Interior).

Uses: Sulfite pulping, water treatment, photo grade.

Waste Problems: The waste solution contains a saturated solution of sulfite which has an immediate oxygen demand if released to the river. Additional recycling and reuse is possible and, if practiced, dumping may be eliminated.

Sodium Sulfate

Producer	Capacity 1/
Allied (B)	45,000
American Cyanamid (O)	13,000
American Enka (R)	56,000
American Potash (N)	250,000
Beaunit (R)	42,000
Climax Chemical (M)	35,000
Diamond Shamrock (B)	50,000
DuPont (M)	30,000
FMC (R)	275,000
Hercules (B,M)	25,000
Huber (O)	8,000
Industrial Rayon (R)	36,000
Koppers (O)	15,000
Lithium Corporation (O)	15,000
Monsanto (O)	35,000
Morton Chemical (M)	120,000
Ozark-Mahoning (N)	200,000
Stauffer (N,O)	200,000
U. S. Borax (O)	30,000
Miscellaneous	25,000
Total	1,505,000

1/ tons/year

B-Bichromate; O-Other; R-Rayon or Cellophane; N-Natural; M-Mannheim or Hargreaves

Production: 1969: 1,500,000 tons/year
1974: 1,800,000 tons/year

Uses: Sulfate pulping, detergents, glass.

Processes: Much of the sodium sulfate is from by-product sources discussed elsewhere. Glauber's salt ($Na_2SO_4.10H_2O$) is made by dissolving salt cake in mother liquor, adding of $CaCl_2$ and lime. The Mg, Ca and Fe are permitted to settle and the mud washed. Crystallization takes place in pans and anhydrous sodium sulfate is prepared by dehydrating Glauber's salt. No new sources or processes are anticipated.

Waste Problems: Disposal of the mud is the primary problem and in-plant control would have little impact on this problem.

Sodium Tripolyphosphate

Producer	Location	Capacity [1]
Allied	N. Claymont, Del.	30,000
AAC	Carteret, N. J.	40,000
FMC	Carteret, N. J.	150,000
FMC	Green River, Wyo.	50,000
FMC	Lawrence, Kans.	75,000
FMC	Newark, Calif.	50,000
Hooker	Adams, Mass.	25,000
Hooker	Dallas, Tex.	25,000
Hooker	Jeffersonville, Ind.	75,000
Monsanto	Augusta, Ga.	25,000
Monsanto	Carondelet, Mo.	100,000
Monsanto	Kearny, N. J.	75,000
Monsanto	Long Beach, Calif.	25,000
Monsanto	Trenton, Mich.	75,000
Olin	Joliet, Ill.	140,000
Stauffer	Chicago, Ill.	40,000
Stauffer	Chicago Heights, Ill.	25,000
Stauffer	Morrisville, Pa.	75,000
Stauffer	South Gate, Calif.	50,000
Virginia-Carolina	Fernald, Ohio	50,000
	Total	1,200,000

[1] tons/year

Production: 1969: 1,200,000 tons
1974: 1,600,000 tons

Uses: Detergents.

Processes: The sodium phosphates are made primarily from furnace acid and soda ash which are reacted in a mix tank and dried in a rotary or spray drier and dehydrated in a calciner. This is followed by annealing and cooling in a tempering unit.

Water Problems: Scrubber waters and vessel washouts are major sources of polluted wastewaters.

SIC 2819 (INDUSTRIAL INORGANIC CHEMICALS)

Aluminum Chloride Anhydrous

Producer		Capacity [1/]
Allied, Elberta, N. Y.		9,000
Dow, Freeport, Texas		5,000
Hercules Alclor, Ravenna, Ohio		2,400
Pearsall, LaPorte, Texas		4,000
Pearsall, Phillipsburg, N. J.		6,000
Stauffer, Baton Rouge, La.		8,000
Stauffer, Elkton, Md.		8,000
Van de Mark, Lockport, N. Y.		2,500
	Total	44,900

1/ tons/year

Production: 1969: 34,000 tons
1974: 44,000 tons

Uses: Ethylbenzene catalyst, dyestuffs, detergent alkylate, ethyl chloride, pharmaceuticals.

Processes: The reaction involves the direct contact of chlorine vapor with molten aluminum. Chlorine is fed below the surface of the aluminum and the product sublimes and is collected by condensing. No change is expected in processing methods.

Waste Problems: The major discharge is a chlorine containing wastewater which could be utilized as a treatment chemical. Recovery of the chlorine by rectification is feasible.

Sulfuric Acid

New Plants Built Since 1966 Include The Following:

Producer	Location	Capacity [1/]
Acid, Inc.	Bonnie, Fla.	2,000,000
Arkla Chemical	Helena, Ark.	180,000
American Cyanamid	Linden, N. J.	250,000

Sulfuric Acid (cont.)

Producer	Location	Capacity 1/
American Oil Co.	Texas City, Tex.	150,000
Allied	Geismar, La.	720,000
American Smelting & Refining Co.	Haydon, Ariz.	250,000
American Zinc	Monsanto, Ill.	146,000
	Columbus, Ohio	64,000
Borden Chemical	Plant City, Fla.	385,000
Bunker Hill	Kellogg, Idaho	100,000
DuPont	Burnside, La.	540,000
---	Memphis, Tenn.	75,000
Freeport Sulfur	Uncle Sam, La.	1,725,000
W. R. Grace	Bartow, Fla.	385,000
Kennecott Copper	Hayden, Ariz.	270,000
	Salt Lake City, Utah	505,000
Mo. Lead Smelting	Iron Co., Mo.	75,000
National Zinc	Bartlesville, Okla.	100,000
Olin	Shreveport, La.	125,000
Sinclair	Ft. Madison, Iowa	540,000
Stauffer	Houston, Texas	720,000
Stauffer	Martinez, Calif.	360,000
Tennessee Corp.	Augusta, Ga.	135,000
Texaco	Port Arthur, Tex.	92,000
Texas Gulf Sulfur	Lee Creek, N. C.	1,000,000
	Total	10,892,000

1/ tons/year

Major merchant producers include:

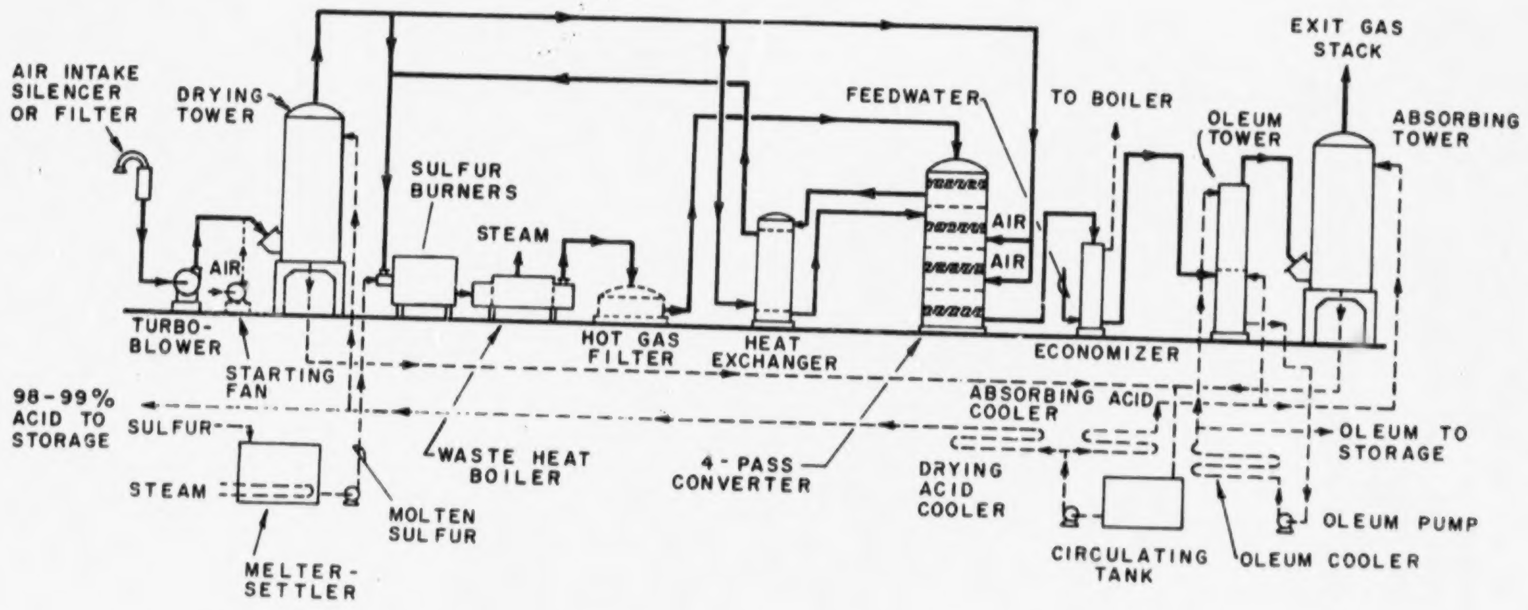
Stauffer Chemical
Allied Chemical
DuPont
American Cyanamid
Tennessee Corporation

Production: 1969: 28,000,000 tons
1974: 34,000,000 tons

Uses: Fertilizer, chemical production, iron and steel pickling, food, petroleum products, metallurgy, TiO_2 production, $(NH_4)_2 SO_4$, alum, rayon.

Processes: Two processes have been used for the production of sulfuric acid - the chamber process and the contact process. Since no new chamber processes have been built for perhaps 30 years, the

FIGURE 8


AIR INTAKE SILENCER OR FILTER
DRYING TOWER
TURBO-BLOWER
AIR
STARTING FAN
98-99% ACID TO STORAGE
SULFUR
STEAM
MELTER-SETTLER
MOLTEN SULFUR
SULFUR BURNERS
STEAM
WASTE HEAT BOILER
HOT GAS FILTER
HEAT EXCHANGER
4-PASS CONVERTER
FEEDWATER
AIR
AIR
TO BOILER
ECONOMIZER
ABSORBING ACID COOLER
DRYING ACID COOLER
CIRCULATING TANK
OLEUM TOWER
EXIT GAS STACK
ABSORBING TOWER
OLEUM TO STORAGE
OLEUM PUMP
OLEUM COOLER

TYPICAL FLOWCHART FOR SULFUR-BURNING CONTACT PLANT

This flow chart is selectively reproduced in content and configuration from Figure 19.4 in the book by R. Norris Shreve, *Chemical Process Industries*, Third Edition, New York, Mc Graw-Hill Book Company, 1967, p. 330

following discussion will center on the contact process. In this process, either sulfur or SO_2 may be the starting point. If sulfur is the starting point, it is melted and burnt with air to SO_2. The SO_2 must be filtered and converted catalytically to SO_3. SO_3 is absorbed in strong sulfuric acid. Present process changes are directed towards the improvement in conversion and recovery because of the air pollution problem.

Waste Problems: Primarily from vessel cleanout, and slab washdown as well as discharge of cooling waters.

SIC 2851 (PAINTS AND ALLIED PRODUCTS)

Paints and Allied Products

Producers: There are several hundred paint companies with several thousand paint plants scattered throughout the country. Paint production tends to be a local product because of the high transportation charges. However, Ohio, Illinois, New Jersey and California are major paint-producing centers. Among the leading concerns are the following:

DuPont
National Lead
Sherwin-Williams
Glidden
Moore
Devoe and Reynolds-Celanese
PPG
DeSoto
Mobil
Inmont
Cook

Production:

	1969 (gal)	1974 (gal)
Paint and Varnishes, Total	904,000,000	1,196,000,000
Trade Sales		
Paint and Varnish	438,000,000	587,000,000
Lacquer	11,000,000	15,000,000
Trade Sales, Total	449,000,000	602,000,000
Industrial Product Finishes		
Paint and Varnish	360,000,000	482,000,000
Lacquer	95,000,000	112,000,000
Industrial Product Finishes, Total	455,000,000	594,000,000

Processes: The manufacture of paints involves primarily mixing in tanks although grinding mills, sand mills, high-speed stone mills and high-speed agitators are being increasingly used in these systems. The process is batch type. Finally, color may be added in a tinting and thinning tank before packaging.

Varnish is a solution of a resin in a drying oil or solvent (shellac). This is accomplished by mixing; in some cases, by heating. Finally, the final product is clarified by filtration or centrifugation followed by aging in large tanks to precipitate grit particles.

There has been little change in the manufacture of paints for a century or more and none is expected.

Waste Problems: The major problems arise from tank washings and dumpings. The presence of latex is a specially difficult problem but collection and recycle of the latex is completely possible as is the multiple reuse of wash waters.

SIC 2871 (FERTILIZERS)

Fertilizers

Producers: Fertilizers are generally made by a large number of production facilities located throughout the country. The basic ingredients include: potash, ammonia, ammonium sulfate, ammonium nitrate, ammonium phosphates, plus other phosphate products all of which are prepared in a limited number of large production facilities. Most of these have already been discussed under SIC 2819 but several including potash, super phosphate, triple super and mixed fertilizers will be discussed in this section.

CONCENTRATED SUPER-PHOSPHATE PLANTS
UNITED STATES

Company	Location	Capacity (thou. tons)
American Cyanamid	Brewster, Fla.	180
Armour Agr. Chem. Co.	Ft. Meade, Fla.	113
Borden Chem. Co.	Port Mantee, Fla.	33
Central Phosphates	Plant City, Fla.	155
Cities Service Oil	Tampa, Fla.	165
Coastal Chemical	Pascagoula, Miss.	135 1/
Continental Oil	Pierce, Fla.	180
El Paso Natural Gas	Georgetown, Idaho	55
Farmland Industries	Lakeland, Fla.	36
W. R. Grace & Co.	Joplin, Mo.	32
	Ridgewood, Fla.	350
Int. Minerals & Chem.	Bonnie, Fla.	203
Kerr-McGee	Baltimore, Md.	...
Mobil Chemical	Nichols, Fla.	130
Occidental Agrilcul.	White Springs, Fla.	188
Phillips Chemical	Pasadena, Tex.	45 1/
F. S. Royster Guano	Mulberry, Fla.	170
J. R. Simplot	Pocatello, Idaho	92
Stauffer Chemical	Garfield, Utah	45
	Tacoma, Washington	23
Swift & Company	Agricola, Fla.	77
Tenn. Valley Authority	Muscle Shoals, Ala.	27 2/
Texas Gulf Sulfur	Lee Creek, N. C.	167
	Total	2,601

1/ Idle facilities
2/ High-analysis 54% P_2O_5 material

AMMONIUM AND DIAMMONIUM PHOSPHATE PLANTS
UNITED STATES

Company	Location	Capacity (thousand tons/year)
AFC, Inc.	Edison, Calif.	28
Allied Chemical	Geismar, La.	-
American Cyanamid	Brewster, Fla.	91
Arizona Agrochemical	Chandler, Ariz.	18
Arkla Chemical	Helena, Ark.	-
Armour Agri. Chem.	Bartow, Fla.	15
	Cherokee, Ala.	75
Borden Chemical	Port Manatee, Fla.	85
	Streator, Ill.	25
	Texas City, Tex.	45
Bunker Hill	Kellogg, Idaho	15
Central Phosphates	Plant City, Fla.	NK 1/
Chevron Chemical	Ft. Madison, Iowa	NK 1/
	Kennewick, Wash.	NK 1/
	Richmond, Calif.	NK 1/
Cities Service Oil	Tampa, Fla.	179
Coastal Chemical	Pascagoula, Miss.	120
Colorado Fuel & Iron	Pueblo, Colo.	7 2/
Continental Oil	Pierce, Fla.	46
Des Plaines Chemical	Morris, Ill.	34
Dominguez Fertilizer	Long Beach, Calif.	15
El Paso Nat. Gas	Soda Springs, Idaho	30
Farmland Industries	Lakeland, Fla.	147
	Joplin, Mo.	67
Ford Motor	Dearborn, Mich.	10 2/
W. R. Grace	Henry, Ill.	100
	Joplin, Mo.	20
	Ridgewood, Fla.	174
Hooker Chemical	Marseilles, Ill.	69
	Taft, La.	175
Int. Min. & Chem.	Bonnie, Fla.	230
Kaiser Steel	Fontana, Calif.	15
Mobil Chemical	Nichols, Fla.	77
Monsanto	Luling, La.	120
Nat. Dist. & Chem.	Danville, Ill.	15
N. J. Zinc	Depue, Ill.	124
Nipak, Inc.	Kerens, Tex.	46
	Tulsa, Okla.	20
NW Coop. Mills	Pine Bend, Minn.	69
Occidental Agri.	White Springs, Fla.	115
	Lathrop, Calif.	10
	Plainview, Tex.	9

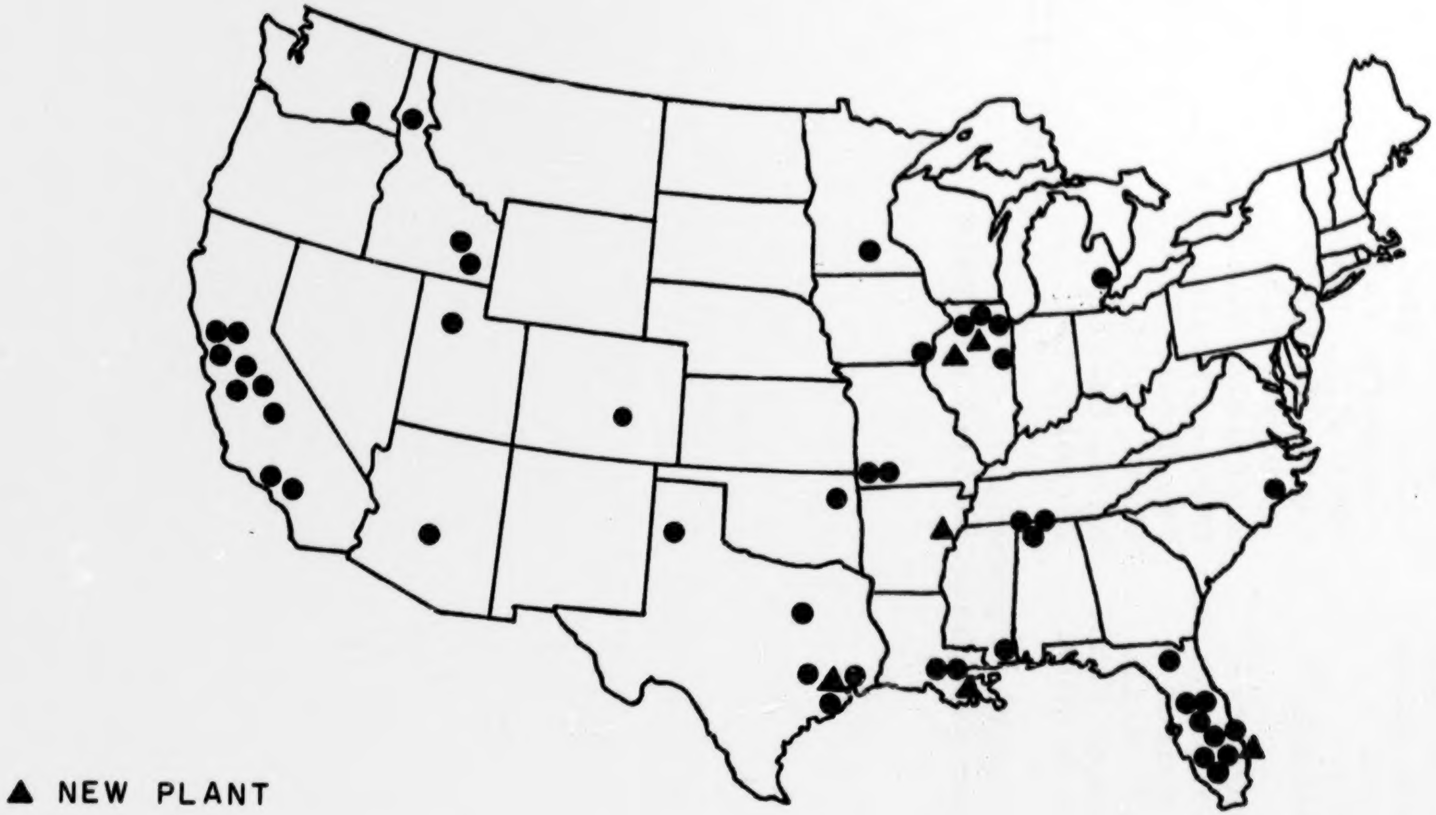
AMMONIUM AND DIAMMONIUM PHOSPHATE PLANTS (cont.)

Company	Location	Capacity (thousand tons/year)
Olin Mathieson Chem.	Pasadena, Tex.	200
Phosphate Chemicals	Houston, Tex.	69
F. S. Royster Guano	Mulberry, Fla.	41
Shell Chemical	Pittsburg, Calif.	12 2/
J. R. Simplot	Pocatello, Idaho	91
Stauffer Chemical	Garfield, Utah	80
Swift	Agricola, Fla.	69
Tennessee Farmers	Sheffield, Ala.	NK 1/
Tennessee Valley Auth.	Muscle Shoals, Ala.	15 2/
Texas Gulf Sulfur	Lee Creek, N. C.	105
Union Oil of Calif.	Brea, Calif.	12
Valley Nitrogen Prod.	Helm, Calif.	35
Western States Chem.	Nichols, Calif.	NK 1/
	Total	3,169

1/ Nitric phosphate process
2/ Diammonium phosphate 21-53-0 analysis

AMMONIUM PHOSPHATE PLANT LOCATIONS

FIGURE 9



PHOSPHATE ROCK MINES
UNITED STATES

Company	Location	Capacity (thousand short tons)
	Florida	
American Cyanamid	Brewster	3,650
Armour Agr. Chem.	Amour Lake Hancock	1,500
Armour Agr. Chem. & Freeport Sulfur	Ft. Meade	2,000
Borden Chemical	Teneroc	1,500
Cities Service	Ft. Meade	2,000
Continental Oil	Pierce	6,500
W. R. Grace	Bonny Lake	1,550
Int. Min. & Chem.	Bonnie	6,000
	Kingsford	2,000
Kerr-McGee, Inc.	Brewster	1,500
Mobil Chemical	Ft. Meade	5,700
Occidental Agril.	White Springs	3,000
Swift & Co.	Watson Silver City	2,325
	North Carolina	
Texas Gulf Sulfur	Lee Creek	3,000
	Tennessee	
Armour Agril. Chem.	Columbia	90
Hooker Chemical	Columbia	750
Mobil Chemical	Mt. Pleasant	200
Monsanto	Columbia	1,000
Presnell Phosphate	Columbia	700
Stauffer Chemical	Mt. Pleasant	600
Tennessee Valley Auth.	Knob Creek Franklin	200
	Western States	
Cominco Ltd.	Garrison, Mont. Phillipsburg, Mont.	1,050
El Paso Nat. Gas	Soda Springs, Idaho	400
Monsanto	Ballard, Idaho	500
Mountain Fuel Supply	Soda Springs, Idaho	NK
New Idria Mining & Chemical	Bakersfield, Calif.	NK
George Relyea	Garrison, Mont.	100
J. R. Simplot	Fort Hall, Idaho Soda Springs, Idaho	1,600

PHOSPHATE ROCK MINES (cont.)

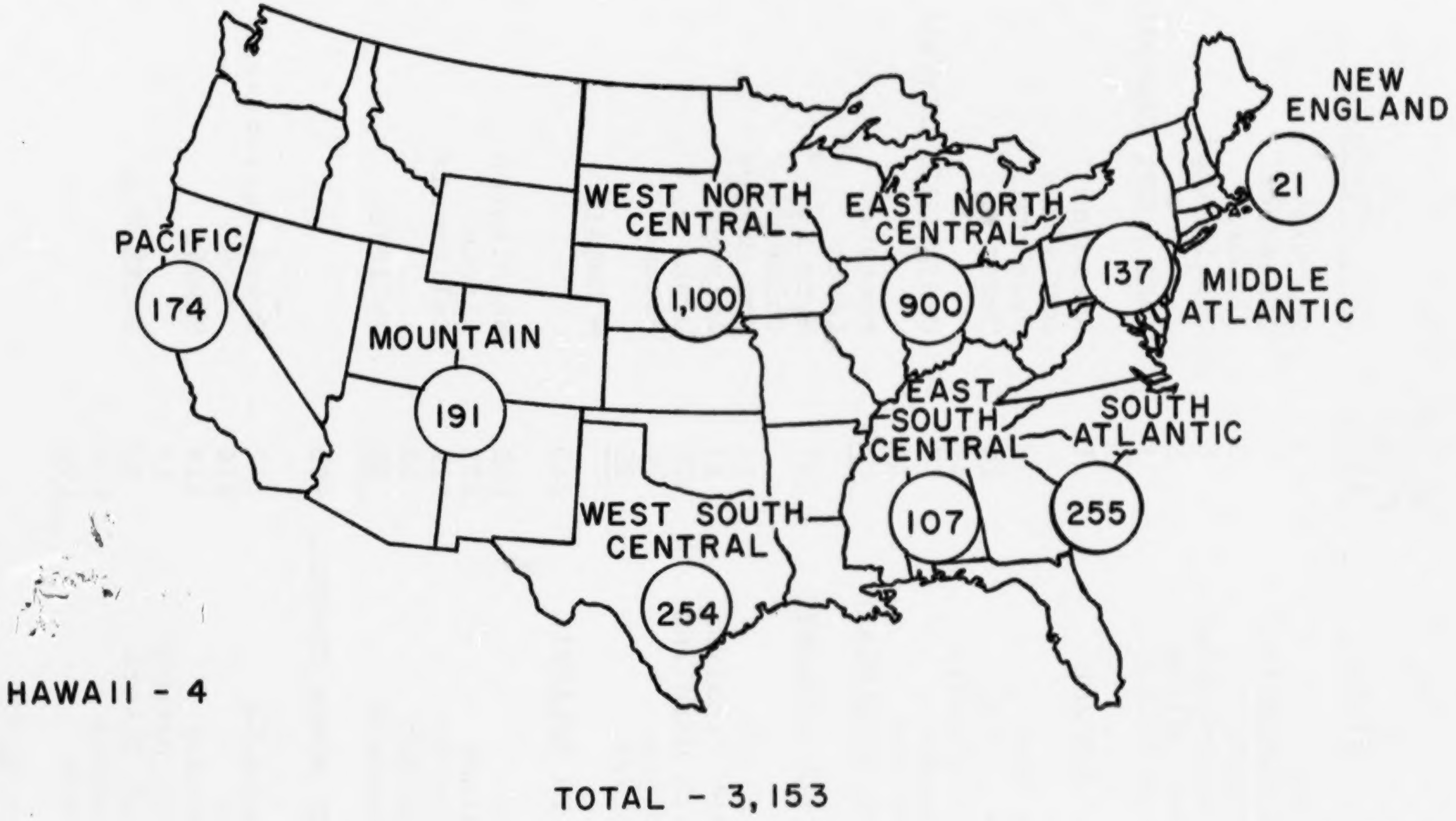
Company	Location	Capacity (thousand short tons)
Stauffer Chemical	Hot Springs, Idaho	200
	Montpelier, Idaho	400
	Cherokee, Utah	200
	Vernal, Utah	350
	Leefe, Wyo.	600
	Total United States	51,165

ESTIMATED NUMBER OF BULK BLEND PLANTS IN THE UNITED STATES

State	No. of Plants 1966
Maine	3
New Hampshire	1
Vermont	3
Massachusetts	5
Rhode Island	5
Connecticut	4
NEW ENGLAND	21
New York	39
New Jersey	20
Pennsylvania	44
Delaware	7
Maryland	26
West Virginia	1
MIDDLE ATLANTIC	137
Virginia	15
North Carolina	41
South Carolina	28
Georgia	76
Florida	95
SOUTH ATLANTIC	255
Ohio	100
Indiana	235
Illinois	428
Michigan	55
Wisconsin	82
EAST NORTH CENTRAL	900
Minnesota	192
Iowa	426
Missouri	224
North Dakota	17
South Dakota	33
Nebraska	116
Kansas	102
WEST NORTH CENTRAL	1,110
Kentucky	35
Tennessee	17
Alabama	37
Mississippi	18
EAST SOUTH CENTRAL	107
Arkansas	50
Louisiana	23
Oklahoma	56
Texas	125
WEST SOUTH CENTRAL	254
Montana	11
Idaho	43
Wyoming	29
Colorado	53
New Mexico	15
Arizona	13
Utah	27
Nevada	--
MOUNTAIN	191
Washington	49
Oregon	42
California	83
PACIFIC	174
Total Continental U.S.	3,149
Hawaii	4
TOTAL U.S.	3,153

ESTIMATED NUMBER OF BULK BLEND FERTILIZER PLANTS

FIGURE 10

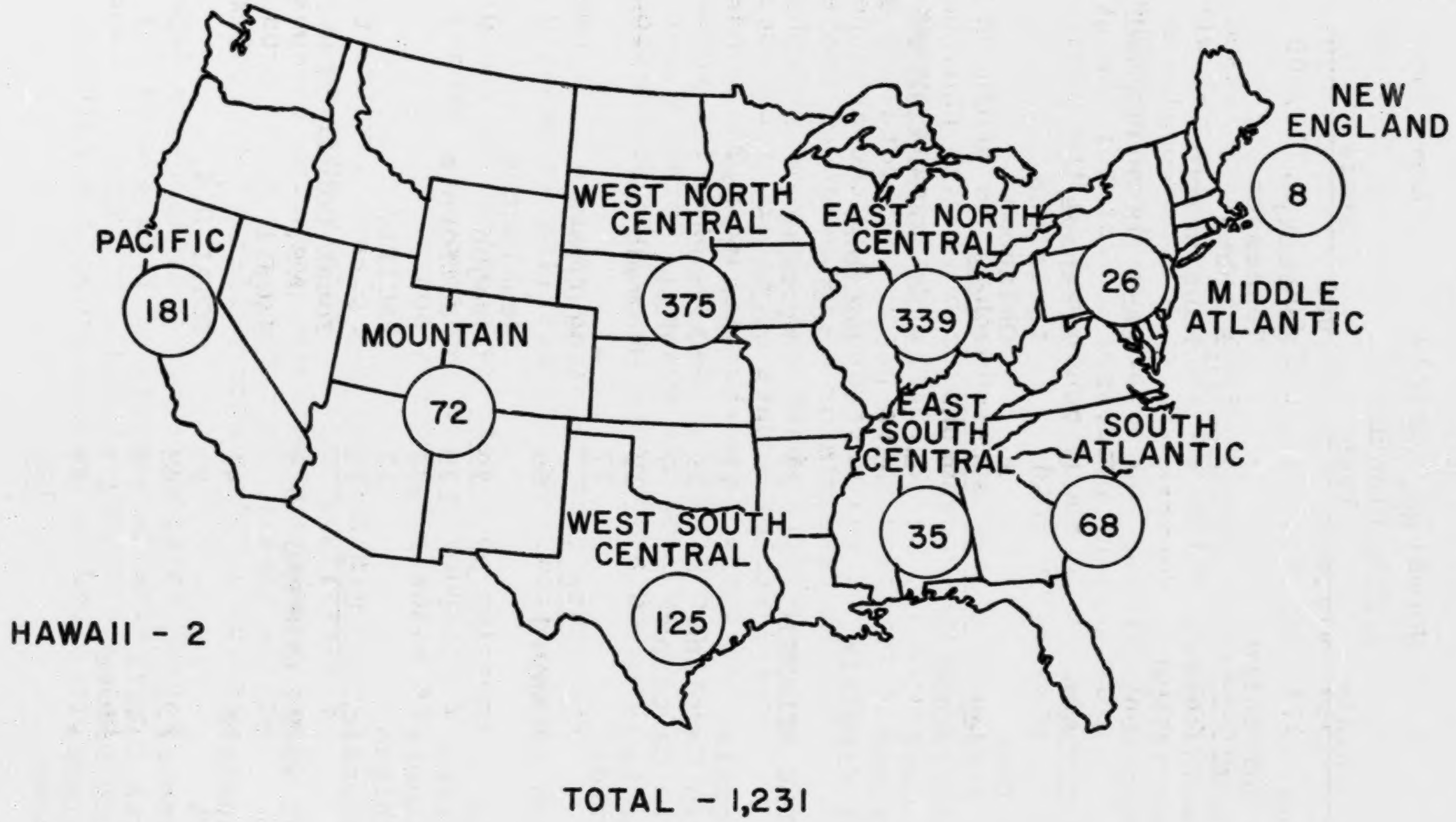

NEW ENGLAND
21
WEST NORTH CENTRAL
EAST NORTH CENTRAL
PACIFIC
174
1,100
900
137
MIDDLE ATLANTIC
MOUNTAIN
191
EAST SOUTH CENTRAL
SOUTH ATLANTIC
WEST SOUTH CENTRAL
107
255
254
HAWAII - 4
TOTAL - 3,153

ESTIMATED NUMBER OF LIQUID MIX PLANTS IN THE UNITED STATES

State	No. of Plants 1966
Maine	1
New Hampshire	-
Vermont	2
Massachusetts	4
Rhode Island	-
Connecticut	1
NEW ENGLAND	8
New York	6
New Jersey	5
Pennsylvania	8
Delaware	1
Maryland	6
West Virginia	-
MIDDLE ATLANTIC	26
Virginia	11
North Carolina	11
South Carolina	7
Georgia	12
Florida	27
SOUTH ATLANTIC	68
Ohio	29
Indiana	129
Illinois	154
Michigan	12
Wisconsin	15
EAST NORTH CENTRAL	339
Minnesota	41
Iowa	85
Missouri	63
North Dakota	5
South Dakota	7
Nebraska	49
Kansas	125
WEST NORTH CENTRAL	375
Kentucky	7
Tennessee	3
Alabama	6
Mississippi	19
EAST SOUTH CENTRAL	35
Arkansas	19
Louisiana	15
Oklahoma	24
Texas	67
WEST SOUTH CENTRAL	125
Montana	4
Idaho	24
Wyoming	5
Colorado	16
New Mexico	1
Arizona	19
Utah	1
Nevada	2
MOUNTAIN	72
Washington	55
Oregon	17
California	109
PACIFIC	181
Total Continental U.S.	1,229
Hawaii	2
TOTAL U.S.	1,231

ESTIMATED NUMBER OF LIQUID MIXED FERTILIZER PLANTS

FIGURE 11


NEW ENGLAND
8
MIDDLE ATLANTIC
26
EAST NORTH CENTRAL
339
WEST NORTH CENTRAL
375
SOUTH ATLANTIC
68
EAST SOUTH CENTRAL
35
WEST SOUTH CENTRAL
125
MOUNTAIN
72
PACIFIC
181
HAWAII - 2
TOTAL - 1,231

Production: (100% APA)

	Normal Super	Triple Super	Ammonium Phosphates	Other Phosphatic Fertilizer
1969	913,000	1,390,000	1,651,000	
1974	900,000	1,800,000	2,200,000	

Processes: Superphosphate is solubilized phosphate rock in which the rock is acidulized with sufficient acid to convert the rock to monocalcium phosphate and gypsum. No separation is made. The waste products and processes except for the gypsum are similar to those generated in the production of phosphoric acid.

Concentrated superphosphate is produced by the reaction of phosphoric acid with phosphate rock producing $Ca\ (H_2PO_4)_2$. No gypsum is produced. The reaction takes place in a rotating granulator. The major waste products are the scrubber waters from the granulator and subsequent cooler exhaust gas scrubbers which contain some phosphoric and considerable amounts of silico fluorides for which a considerable market exists. The condensate from the acid preheater can be used for scrubber water to close loop the system. Normal super production is being superseded by triple production.

Phosphate rock handling results in a heavily turbid water flow. Solids settling is usually practiced.

Ammonium phosphate is produced by the direct contact of phosphoric acid and ammonia. Vessel washout is the major pollutional source.

Liquid mix and dry mix plants involve the blending of fertilizer base materials such as superphosphate, urea, ammonium nitrate, ammonium phosphate and potash thereby producing the final product. Vessel washout is the major pollutional problem.

Potash is produced from sedimentary deposits of syluinite (a mixture of K Cl and Na Cl) and langbeinite ($K_2SO_4 \cdot 2MgSO_4$), primarily. Langbeinite is processed to produce potassium sulfate. The Trona, California, salts are another important salt. Solar evaporation at Great Salt Lake is also practiced. The biggest single source of new potash is the deep deposit in Saskatchewan, Canada which will be developed by conventional and solution mining.

Some of the potash is produced by fractional crystallization but the syluinite deposits are handled by either soap flotation or fractional solution. In both processes, slimes and reject salt solutions are present to create pollution problems. The reject salt solutions may contain small amounts of flotation agents such as starch and amines. It is possible through the careful use and selection of these agents to minimize losses. Reuse and recovery of the slimes and salt solutions may be practiced. Of course, since great stretches of land are available, disposal is not generally a problem. In Europe, the great potash mines of the Alsace are one of the main polluters of the Rhine. Recovery of the salt is totally feasible. The present trend is towards partial solution of KCl as practiced in Canada since this area will be the major source in the next decade.

Complex fertilizer is prepared by reaction of ammonia, phosphoric acid, nitric acid and phosphate rock in acidulation tanks. The final slurry is mixed with potassium chloride (potash). The product may be spherodized, granulated or coated. A dust collector is used to recover fines.

Generally, the entire system is kept dry for process reasons but vessel and slab washdowns produce wastewater problems. Fluorine in fume scrubbing water may be a problem.

TVA has been successful in developing direct ammination and acidulation processes aimed at producing higher concentration fertilizers. Most of these processes are carried out dry, but this is not the universal practice and those processes carried out in a wet state create steady waste streams. The trend towards high analysis fertilizer is expected to continue in the future.

POTASH PLANTS
UNITED STATES AND CANADA

Company	Location	1969 Capacity (thou. tons)
	United States	
American Metal Climax	Carlsbad, N. M.	600
Am. Potash & Chem.	Trona, Calif.	235
	Carlsbad, N. M.	450
	Carlsbad, N. M.	450
	Wendover, Utah	66
	Carlsbad, N. M.	300
	Ogden, Utah	270
	Carlsbad, N. M.	350
	Carlsbad, N. M.	620
	Moab, Utah	350
U.S. Borax & Chem.	Carlsbad, N. M.	550
Agri. Minerals	Davenport, Calif.	
Dow Chemical	Midland, Mich.	10
N. Am. Cement	Security, Md.	
	Total	4,251
	Canada	
	Lanigan, Sask,	600
	Delisle, Sask.	600
	Saskatoon, Sask.	600
Int. Min. & Chem.	Esterhazy, Sask.	2,460
Calium Chemicals	Belle Plaine, Sask.	360
	Viscount, Sask.	720
Potash Corp. of Am.	Lake Patience, Sask.	430
U.S. Borax & Chem.	Saskatoon, Sask,	900
	Total	6,670
	Total North America	10,921

SIC 2879 (INORGANIC PESTICIDES)

Inorganic Pesticides

Producers: Data not available

Production: (tons/year)	1969	1974
Arsenic compounds	6,000	5,000
Sulfur	210,000	150,000

Processes and Waste Problems: In general, inorganic compounds have been replaced by organic compounds. The major inorganic pesticides are the following:

lead arsenate
sulfur
carbon bisulfide
hydrogen cyanide
fluorine
lime-sulfurs
Bordeaux mixture
mercury chlorides
sodium chlorate
sodium arsenite
ammonium sulfamate

This review does not consider the organophosphorous compounds which are gaining major importance in the industry. Neither will this review detail many of the above listed chemicals because their use in this particular application is minor compared to other uses for them.

Lead arsenate is prepared from lead oxide which is dissolved in acetic and nitric acid and arsenic acid is added. Lead arsenate is removed by filtration. The mixture of nitric and acetic acid is reused three times. Thus, 0.15 pounds of nitric acid per pound of product and a similar amount of acetic acid is discarded or must be treated and recycled. It is obvious that recycle would result in greatly reduced waste problems.

Sulfur is made by milling sulfur to 325 mesh, emulsifying molten sulfur, heating mixtures of sulfur with bentonite and using flotation sulfur obtained from the recovery of the element from hydrogen sulfide from gases. Washout streams containing fine sulfur particles can be recovered.

Lime-sulfur is prepared by boiling a mixture of lime, sulfur and water to a dry mixture.

Bordeaux mixture is prepared by mixing copper sulfate, lime and water. Both lime sulfur and Bordeaux mixture are generally prepared in the field and wastewater problems are not significant.

Mercury chlorides are prepared in the following fashion. Mercuric chloride is prepared by the direct reaction of mercury and chlorine and mercurous chloride is made by reducing mercuric chloride with mercury. Wastewater problems result from vessel washout.

Considering the fading nature of the industry, no process changes are expected.

SIC 2892 (EXPLOSIVES)

Explosives

Producer: Data not available

Production: 1969: ($) 264,000,000
1974: ($) 322,000,000
(weight data not available)

Processes and Waste Problems: Nitrocellulose is prepared first by boiling cotton linters in dilute caustic and bleaching with chlorate. The cotton is then dried and nitrification with nitric acid and sulfuric acid takes place in a nitrator. The charge is dropped into a centrifuge for drying.

Two waste problems exist. The kiering caustic solution must be dumped from time to time and this is a serious waste load. Regeneration of the caustic solution by dialysis or other membrane processes is possible but not practical.

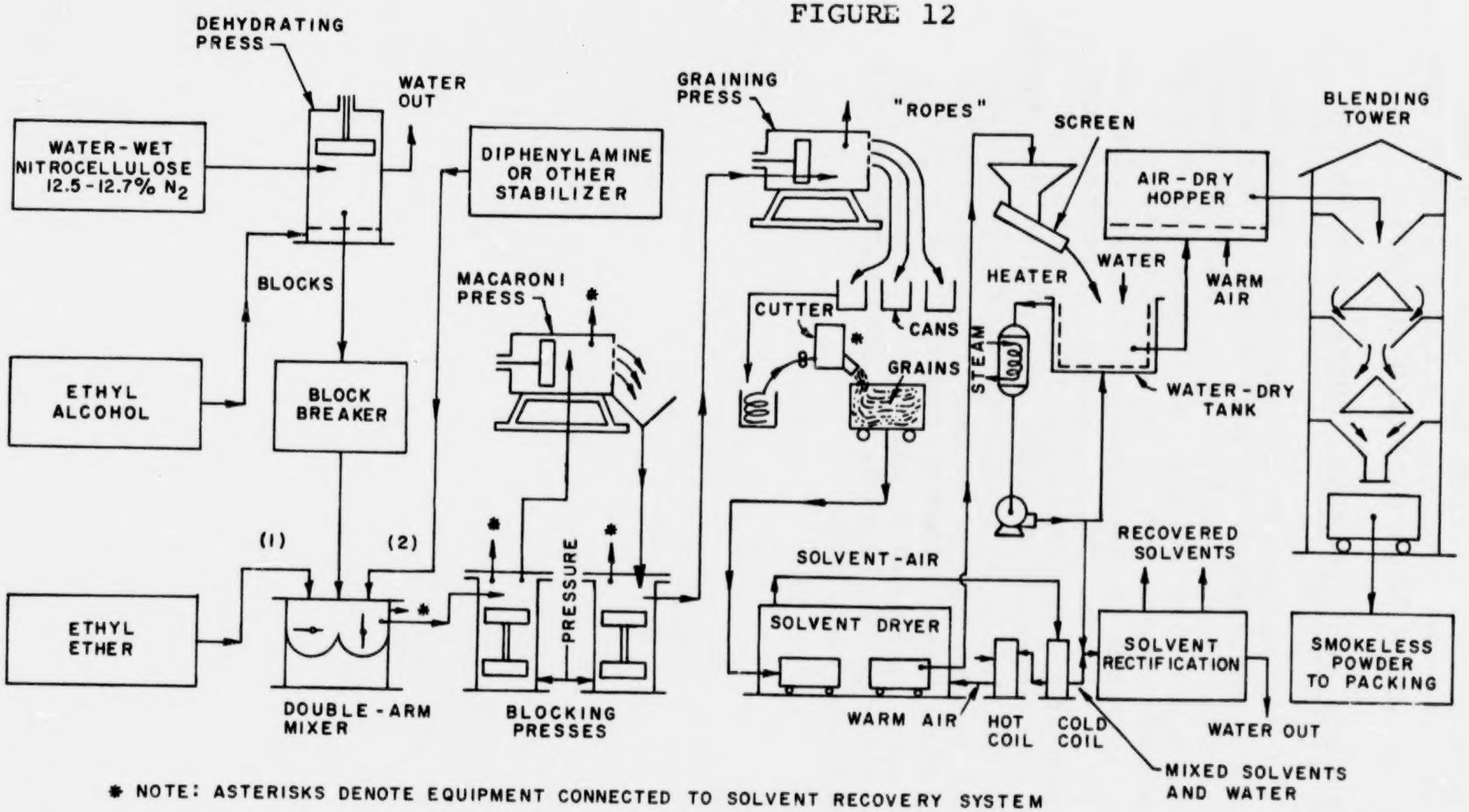
The waste acid amounts to 0.5 pounds of sulfuric and 0.35 pounds of nitric. Some of this acid is sent for concentration, some is sold and the remainder is discharged. Reuse of this acid should be possible if careful measures are taken.

Naturally, washouts of vessels and slabs can also produce major waste treatment problems.

Smokeless powder is washed and beaten to remove free acid and destroy any unstable sulfate esters that may have been formed. The final product is colloidized by mixing with alcohol, ether, diphenylamine and other modifying agents. Again, the washing of the nitro cellulose produces a waste containing sulfuric and nitric acid which can be reclaimed in a fortifying plant.

TNT is produced by the three stage nitrification of toluene followed by soda ash and sodium sulfate washes. The wash water contains considerable amounts of alkalies and sodium dinitrosulfanates.

FIGURE 12


DEHYDRATING PRESS
WATER OUT
WATER-WET NITROCELLULOSE 12.5-12.7% N₂
BLOCKS
ETHYL ALCOHOL
BLOCK BREAKER
ETHYL ETHER
(1)
(2)
DOUBLE-ARM MIXER
DIPHENYLAMINE OR OTHER STABILIZER
MACARONI PRESS
*
PRESSURE
BLOCKING PRESSES
GRAINING PRESS
"ROPES"
CUTTER
CANS
GRAINS
SOLVENT-AIR
SOLVENT DRYER
WARM AIR
HOT COIL
COLD COIL
STEAM
HEATER
SCREEN
WATER
WATER-DRY TANK
AIR-DRY HOPPER
WARM AIR
RECOVERED SOLVENTS
SOLVENT RECTIFICATION
WATER OUT
MIXED SOLVENTS AND WATER
BLENDING TOWER
SMOKELESS POWDER TO PACKING

* NOTE: ASTERISKS DENOTE EQUIPMENT CONNECTED TO SOLVENT RECOVERY SYSTEM

FLOWCHART FOR SMOKELESS POWDER

This flow chart is selectively reproduced in content and configuration from Figure 22.4 in the book by R. Norris Shreve, *Chemical Process Industries*, Third Edition, New York, Mc Graw-Hill Book Company, 1967, p. 390

Ammonium nitrate - Fuel oil (AN) are produced by mixing and shaping of the two ingredients. A major waste source is from the washing of the equipment, thereby producing a waste stream containing oil and a high nitrogen content.

Nitroglycerin and dynamite. Nitration of the glycerin takes place in the presence of sulfuric acid. The nitroglycerin is separated from the spent acids and washed several times. The spent acid is recycled and fortified. About 80 pounds of sulfuric and 160 pounds of nitric are wasted from the system per ton of nitroglycerine. Dynamite is made by adsorbing nitroglycerine on agents such as wood flour, ammonium nitrate or sodium nitrate. Nonfreezing dynamite can be made by the addition of ethylene glycol dinitrate to lower the freezing point of nitroglycerine. A typical waste from a dynamite-nitroglycerine facility has the following composition: pH-7, COD-350 ppm, TDS-10,800 ppm, SS-40, sodium-150, ammonia-nitrogen-1270 ppm, nitrate nitrogen-550 ppm, sulfates-1000 ppm.

APPENDIX C

COSTS OF UNIT WASTEWATER TREATMENT PRACTICES

Neutralization
Deep Well Disposal
Reverse Osmosis
Electrodialysis
Ion Exchange
Multiple Effect Evaporation
Solar Evaporation
Cooling Towers

COSTS OF UNIT WASTEWATER TREATMENT PRACTICES

An envelope of extreme values of TDS and flow rate that have been considered for the subsequent cost calculations are shown in Figure 1. The following are the combinations within the triangle of flow, acidity, suspended and dissolved solids chosen for the study:

Flow rate	0.5, 1.0, 10.0, 50.0 mgd
Acidity	500, 1000, 20,000 mg/l (as $CaCO_3$)
Suspended solids	100, 500 mg/l
TDS	3000, 30,000, 150,000 mg/l

The flow sheet used for the cost calculations is shown in Figure 2. When neutralization is not required, the neutralization portion will be bypassed.

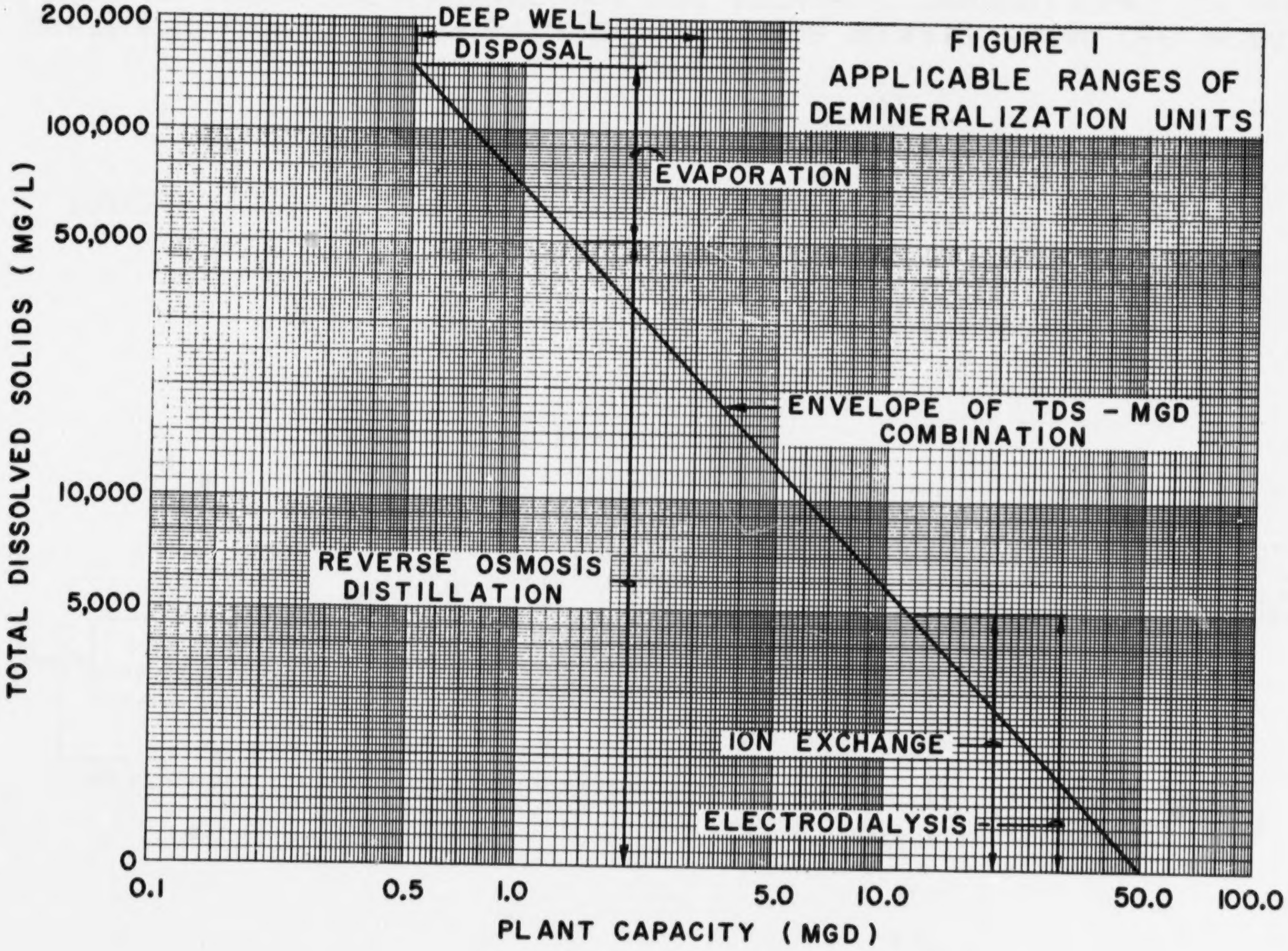


FIGURE I
APPLICABLE RANGES OF DEMINERALIZATION UNITS

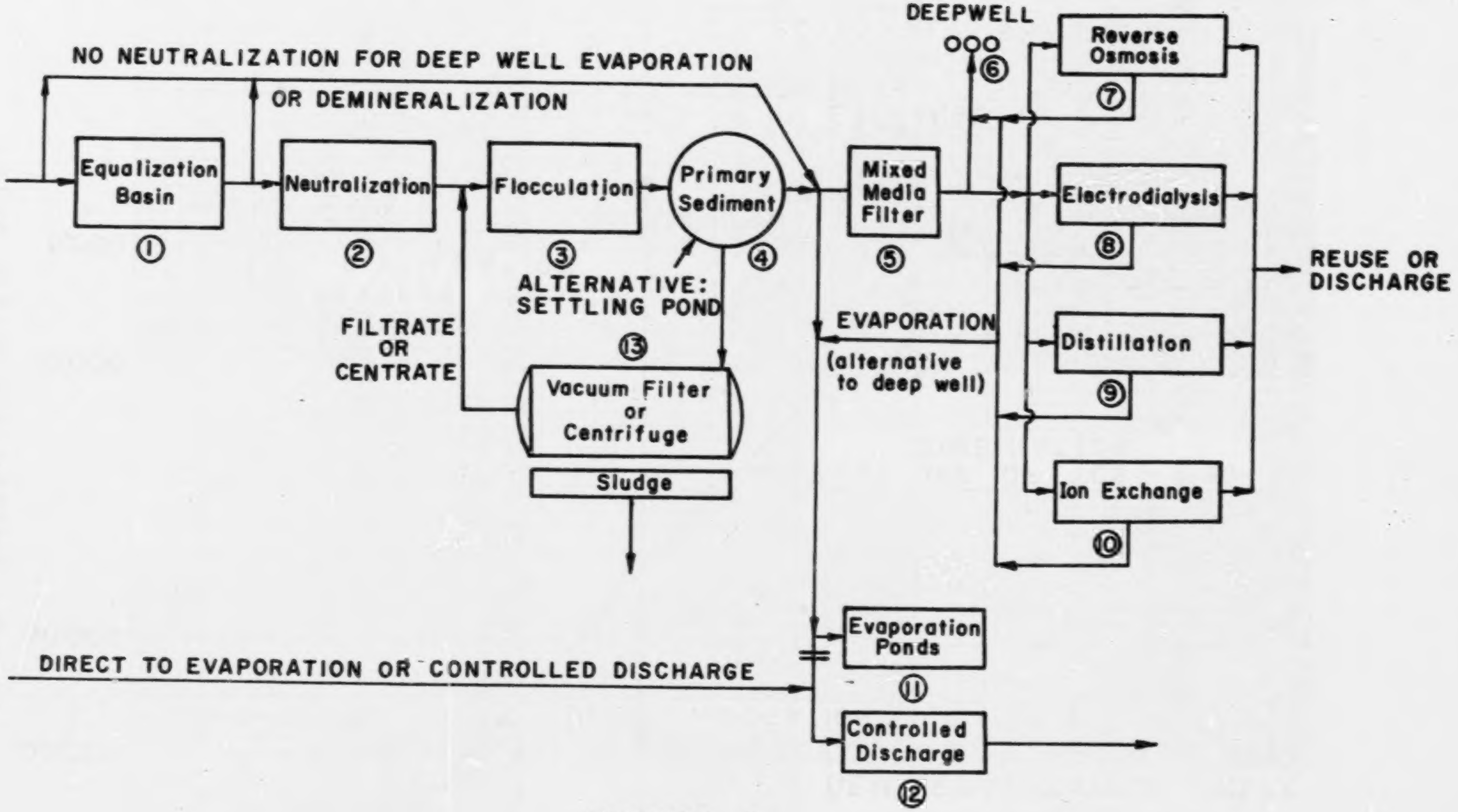

NO NEUTRALIZATION FOR DEEP WELL EVAPORATION
OR DEMINERALIZATION
Equalization Basin
①
Neutralization
②
Flocculation
③
Primary Sediment
④
ALTERNATIVE: SETTLING POND
FILTRATE OR CENTRATE
⑬
Vacuum Filter or Centrifuge
Sludge
Mixed Media Filter
⑤
DEEPWELL
⑥
Reverse Osmosis
⑦
Electrodialysis
⑧
Distillation
⑨
Ion Exchange
⑩
EVAPORATION
(alternative to deep well)
REUSE OR DISCHARGE
DIRECT TO EVAPORATION OR CONTROLLED DISCHARGE
Evaporation Ponds
⑪
Controlled Discharge
⑫

FIGURE 2
SCHEMATIC LAYOUT OF TREATMENT PLANT FOR WASTES FROM THE INORGANIC CHEMICAL INDUSTRY SHOWING VARIOUS POSSIBLE COMBINATIONS OF UNITS

NEUTRALIZATION

Neutralization of inorganic industrial wastes usually implies the use of some form of lime for the neutralization of acidic wastes or sulfuric acid for the neutralization of alkaline wastes. Acidic wastes are more prevalent and neutralization presents more of a problem with such wastes. All forms of inexpensive neutralizing material produces sludge which is difficult to dewater. For large scale plants, economy requires the use of some form of lime or limestone for treatment. Hydrated lime has been used extensively for neutralization of acidic wastes but recent studies (1) seem to indicate that greater economy could be achieved by the use of limestone, both from the viewpoint of lower cost of the alkali combined with a lower cost of sludge dewatering (2). Few cost figures are available for limestone treatment facilities, and for the purpose of this study, only hydrated lime treatment will be considered.

Neutralization with lime combined with aeration will remove iron as a necessary consequence since the solubility of ferric ions decreases rapidly above a pH of 3.0. Manganese, alumina, and silica, as well as many of the heavy metal ions, also are removed by lime neutralization resulting in a decrease in total hardness.

The capital costs were calculated for a flow sheet shown in Figure 3. Equalization capacity is required to supply a constant flow of waste to the flash mixer. Lime from the lime storage tank is fed into the slaker together with some clarified effluent. Lime slurry from the slaker is added to the waste stream in a flash mixer. After flash mixing, the mixture is flocculated and aerated. Next the waste is thickened in a clarifier-thickener or in a sludge settling pond. The underflow from the thickeners with 2% to 3% solids may be passed on to a vacuum filter

---

(1) Mihok, E. A., et al "Mine Water Research-The Limestone Neutralization Process, U.S. Bureau of Mines R.I. 7191, September, 1968.

(2) Rice & Company, "Engineering Economic Studies of Mine Drainage Control Techniques," Appendix B to Acid Mine Drainage in Appalachia, A Report by the Appalachian Regional Commission.

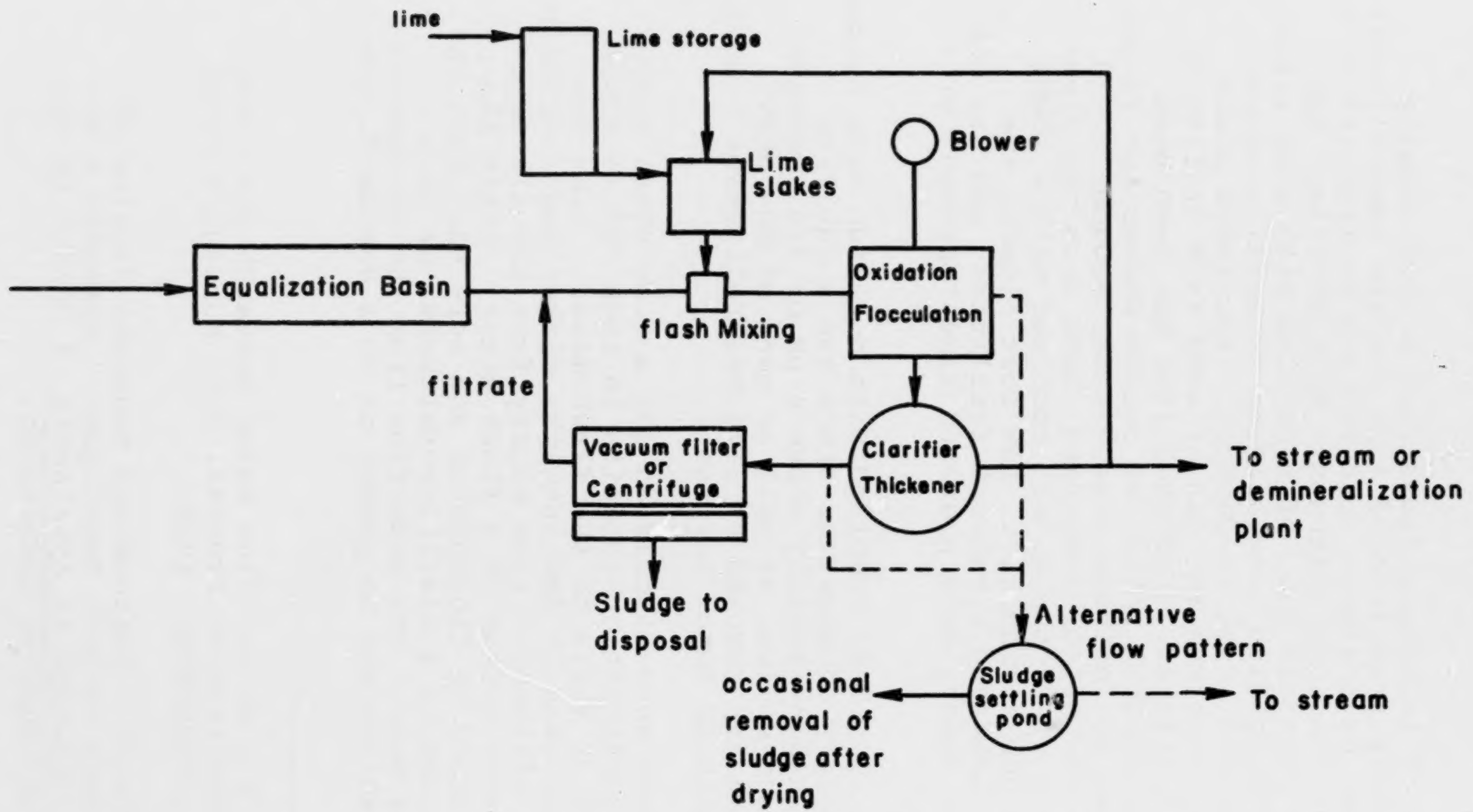

lime
Lime storage
Lime slakes
Blower
Equalization Basin
flash Mixing
Oxidation Flocculation
filtrate
Vacuum filter or Centrifuge
Clarifier Thickener
To stream or demineralization plant
Sludge to disposal
Alternative flow pattern
occasional removal of sludge after drying
Sludge settling pond
To stream

FIGURE 3
FLOW SHEET FOR NEUTRALIZATION PLANT

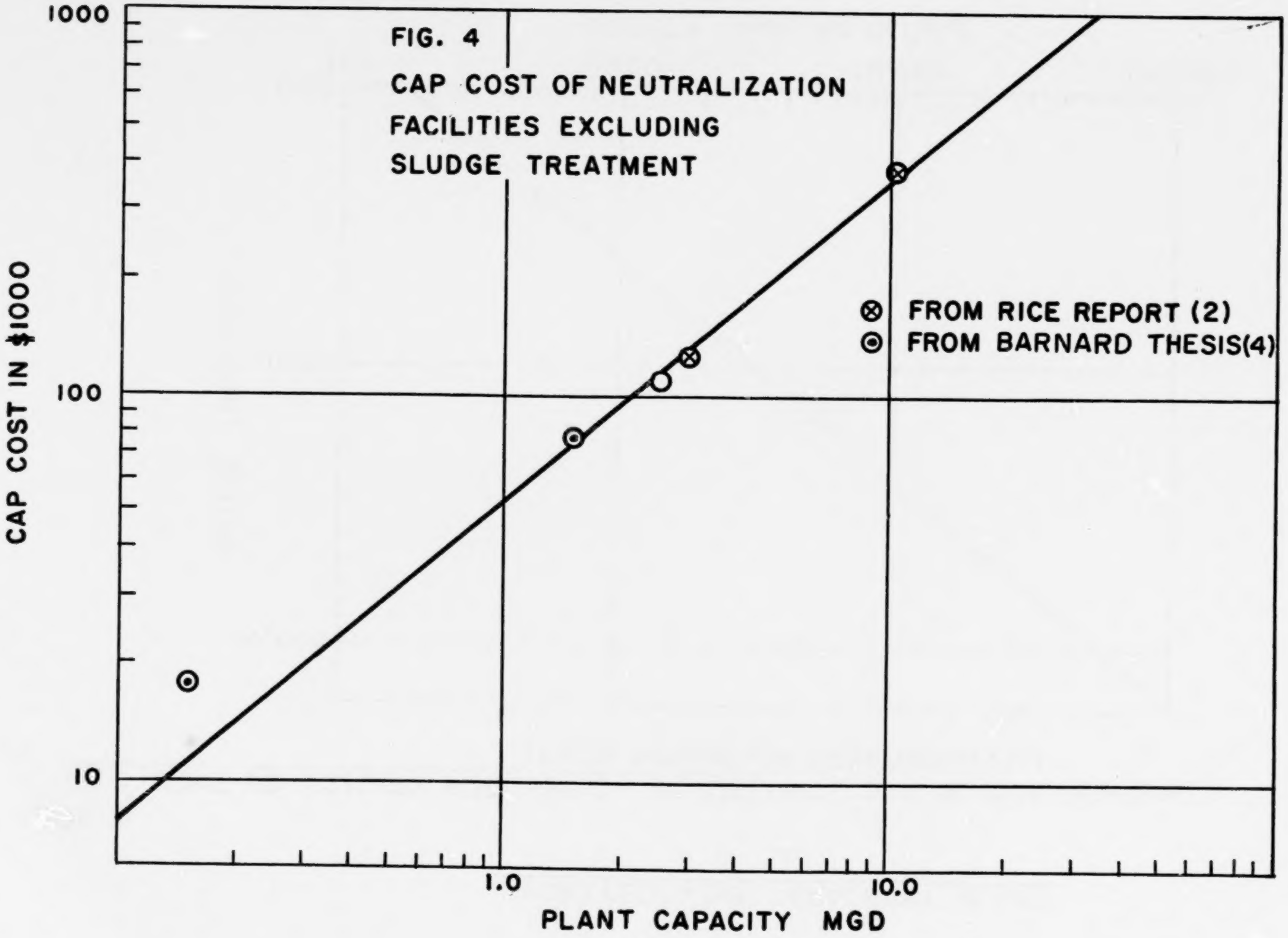


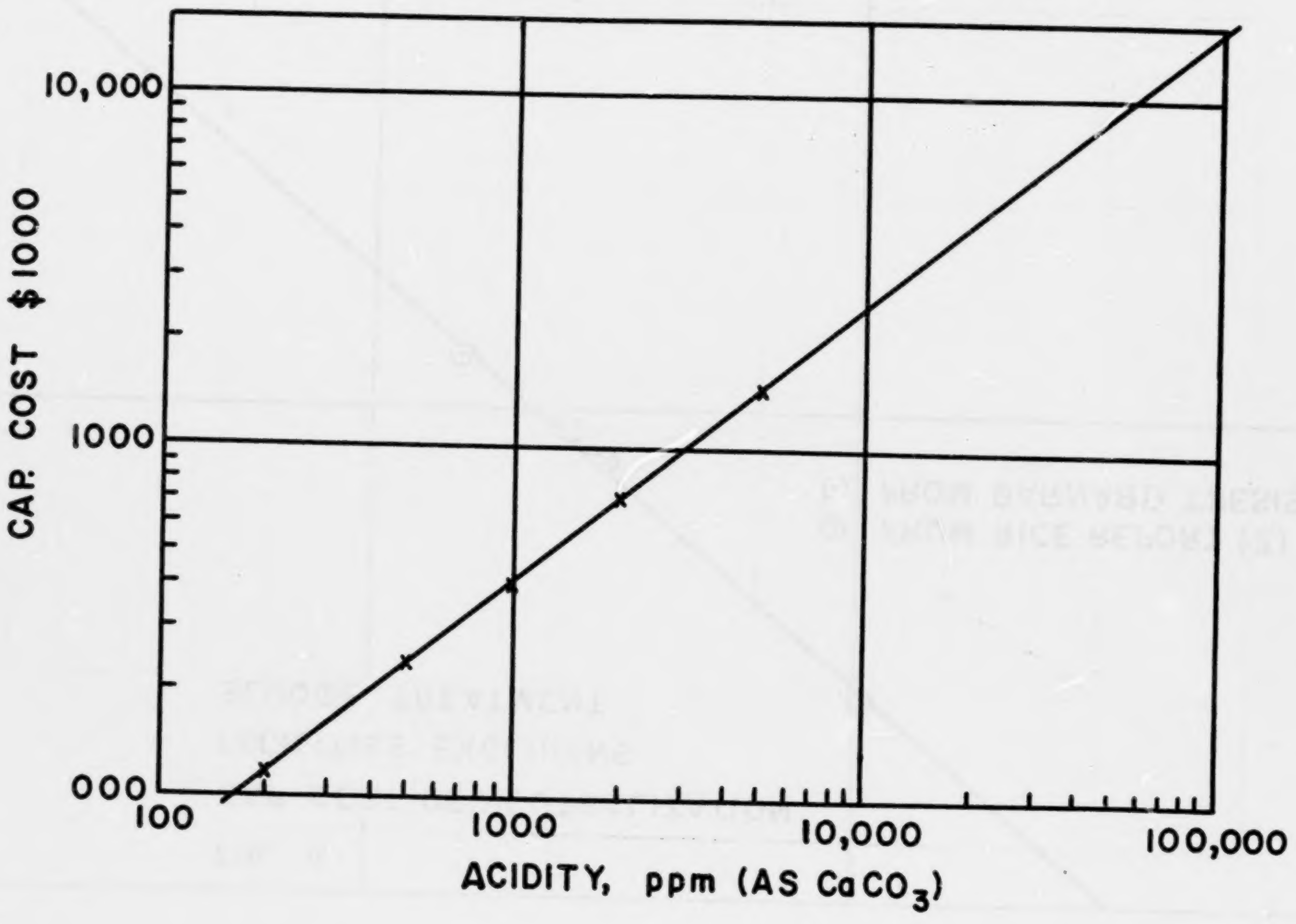
FIG. 4

CAP COST OF NEUTRALIZATION FACILITIES EXCLUDING SLUDGE TREATMENT

HYDRATED LIME TREATMENT PLANT

FIGURE 5

CAP. COST. VS ACIDITY FOR 1 MGD PLANT (INCLUDING SLUDGE DISPOSAL)
(FROM OPERATION YELLOWBOY) (2)



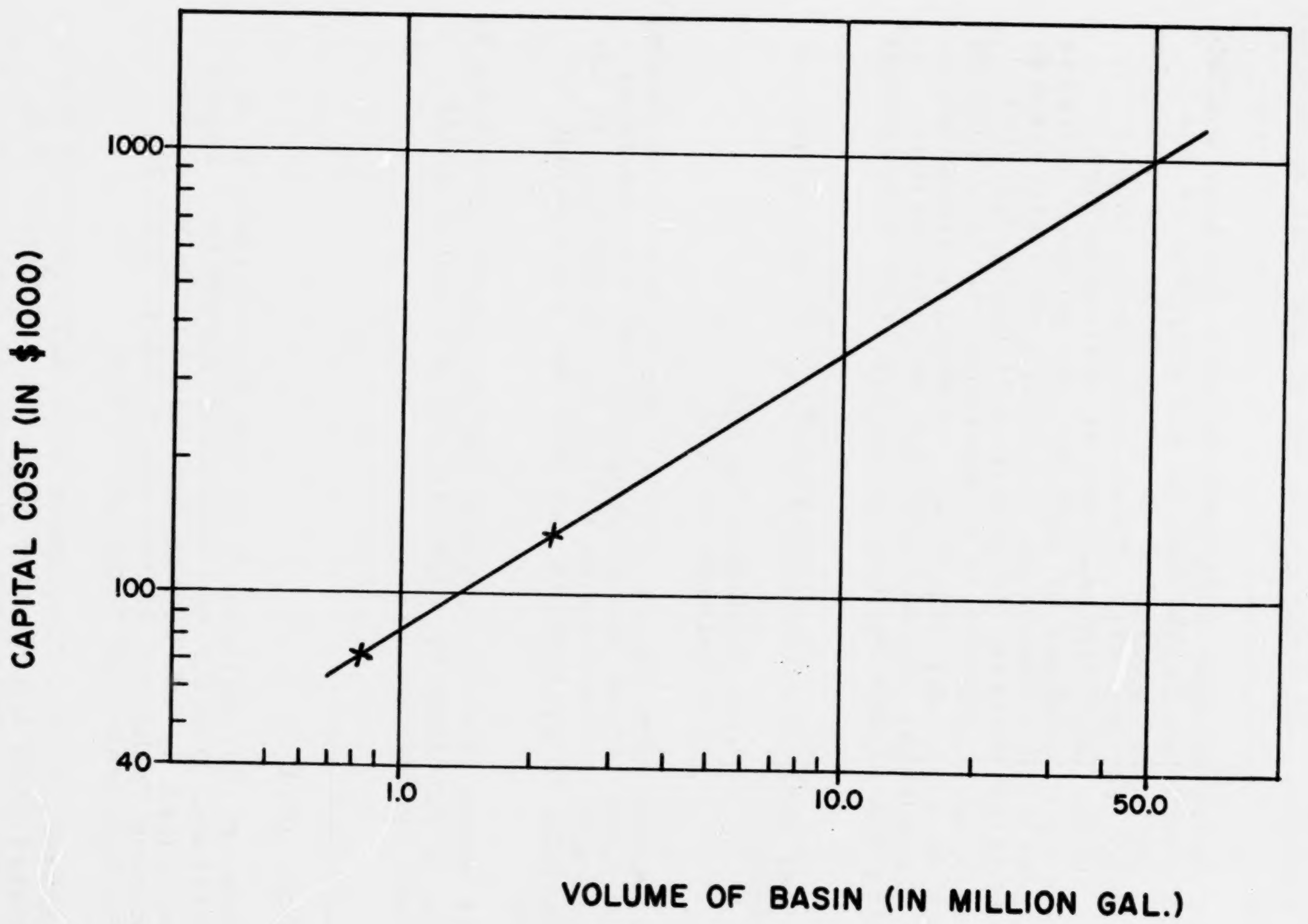


FIG. 6 CAPITAL COST OF EQUALIZATION BASINS REF. (3)

or a centrifuge for dewatering or may be discharged to a dewatering pond. Sludge will be dewatered mechanically to approximately 20% solids at which consistency it can be trucked to disposal. If abundant land is available, the waste will be discharged from the flocculator directly into a settling pond. If land is scarce but available within pumping distance, only the thickened sludge will be settled in a pond.

Costs for hydrated lime treatment of acid drainage including sludge disposal by thickening and disposal of the slurry in ponds are presented in a report on the economics of acid mine drainage (2). These cost curves show a decrease in the unit capital cost of neutralization facilities with increase of acidity, but no such decrease in unit cost with increase in the volume of waste treated daily. This is contrary to previous findings (4) that the overall cost increase is proportional to flow rate to the power of 0.83 (see Figure 4). Combining these two values, the general overall cost for neutralization, thickening and sludge holding ponds can then be expressed as:

$$\text{Capital Cost (in \$1000)} = 172\ Q^{0.83} A^{0.79} \quad \text{(see Figure 5)}$$

where

Q = flow rate in mgd
A = acidity in mg/l

From available cost curves for (1) the equalization basin, (2) lime plant, mixes and flocculator (3) the clarifier thickener and (4) the vacuum filter or centrifuge, it was also possible to synthesize the cost for full sludge dewatering.

The cost curve for equalization basins (shown in Figure 6) is based on findings by Chow (3) and additional costs determined by Barnard (4).

---

(2) Rice, ibid

(3) Chow, C. S., Malina, J. F. and Eckenfelder, W. W., "Effluent Quality and Treatment Economics," Report published by the Center for Research in Water Resources Technical Report EHE 07-6801, CRWR 28, The University of Texas at Austin.

(4) Barnard, J. L., "Treatment Cost Relationships for Wastes from the Organic Chemical Industry," M.S. Thesis, The University of Texas at Austin, June, 1969.

The cost curve for the lime plant mixer and flocculator is based on costs extracted by Barnard (4) and additional costs obtained from Operation Yellow Boy (2). These curves shown little variation with acidity which influences mainly the sludge handling units, but they are dependent on the plant size.

Costs for the clarifier thickener were based mainly on flow since clarification and thickening is combined into one unit. Clarification requires a minimum overflow rate for effluent control and this will determine the size of the unit. The amount of thickening obtained is then calculated from zone settling considerations to determine the consistency of the thickener underflow. Costs were obtained from the Mine Drainage Report (2) and calculated from parameters obtained from a laboratory study of neutralized acid wastes.

The size of the clarifier itself is based on an overflow rate of 700 gpd/ft^2. In order to produce an effluent suitable for further use or treatment, it will be necessary to use polymers to reduce the suspended solids in the effluent and to filter the effluent. The thickener design was based on values from laboratory studies (5) as shown in Figures 7 and 8.

The design is based on the following mathematical model by Edde and Eckenfelder (6):

$$\frac{Cu}{Ci} - 1 = \frac{k_B}{(ML)^n}$$

where

Cu = solids concentration of the underflow in mg/l
Ci = influent solids concentration in mg/l
k_B = constant depending on Ci as shown in Figure 8
ML = mass loading in lbs. solids per day/sq. ft. of tank surface

---

(2) Rice, ibid

(4) Barnard, ibid

(5) Atlas Chemicals, Marshall, Texas, Private Report.

(6) Edde, H., and Eckenfelder, W. W., "Theoretical Concept of Gravity Sludge Thickening," Presented at 40th Annual Conference of the Water Pollution Control Federation, New York, New York, October 8, 1967.

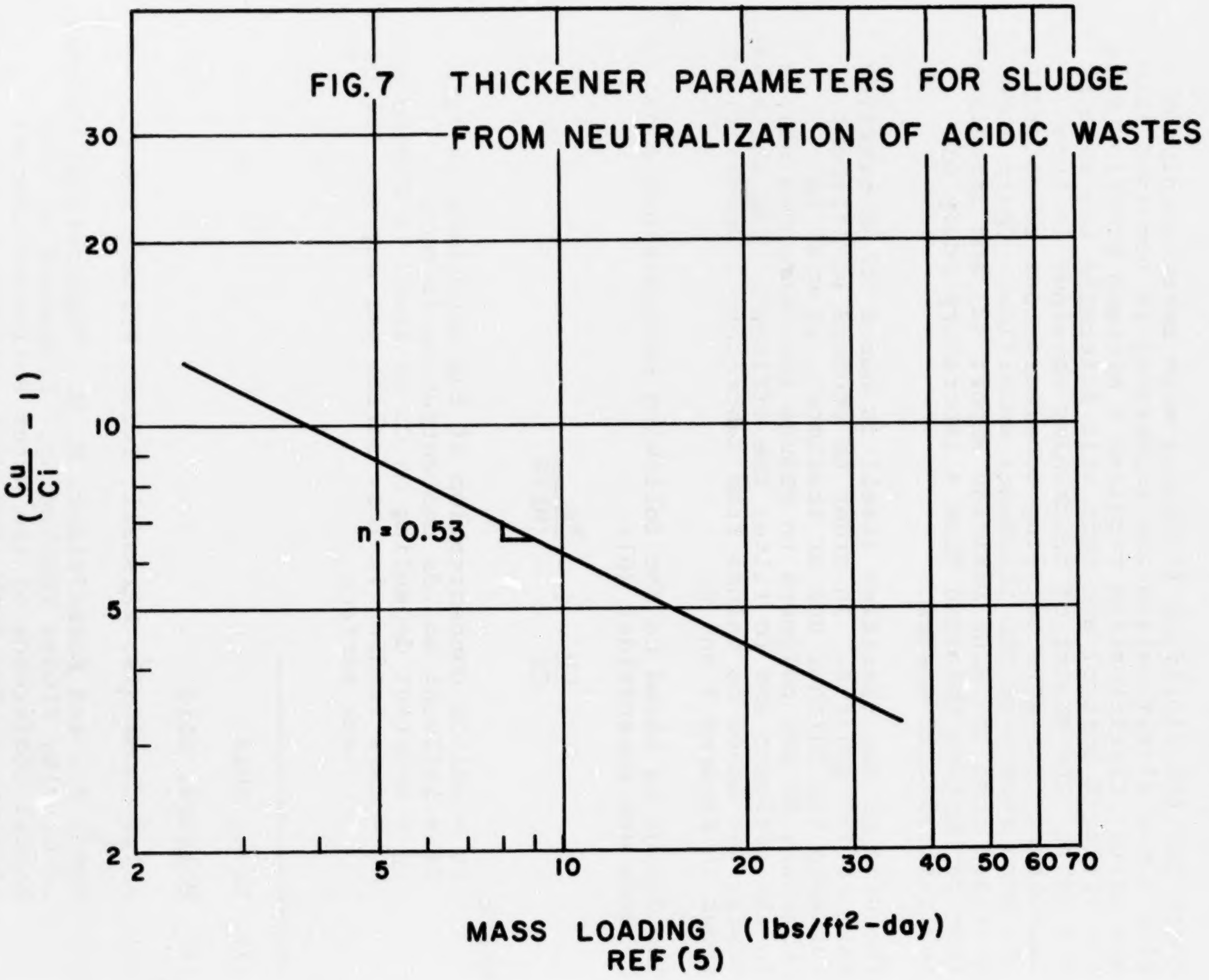


FIG.7 THICKENER PARAMETERS FOR SLUDGE FROM NEUTRALIZATION OF ACIDIC WASTES

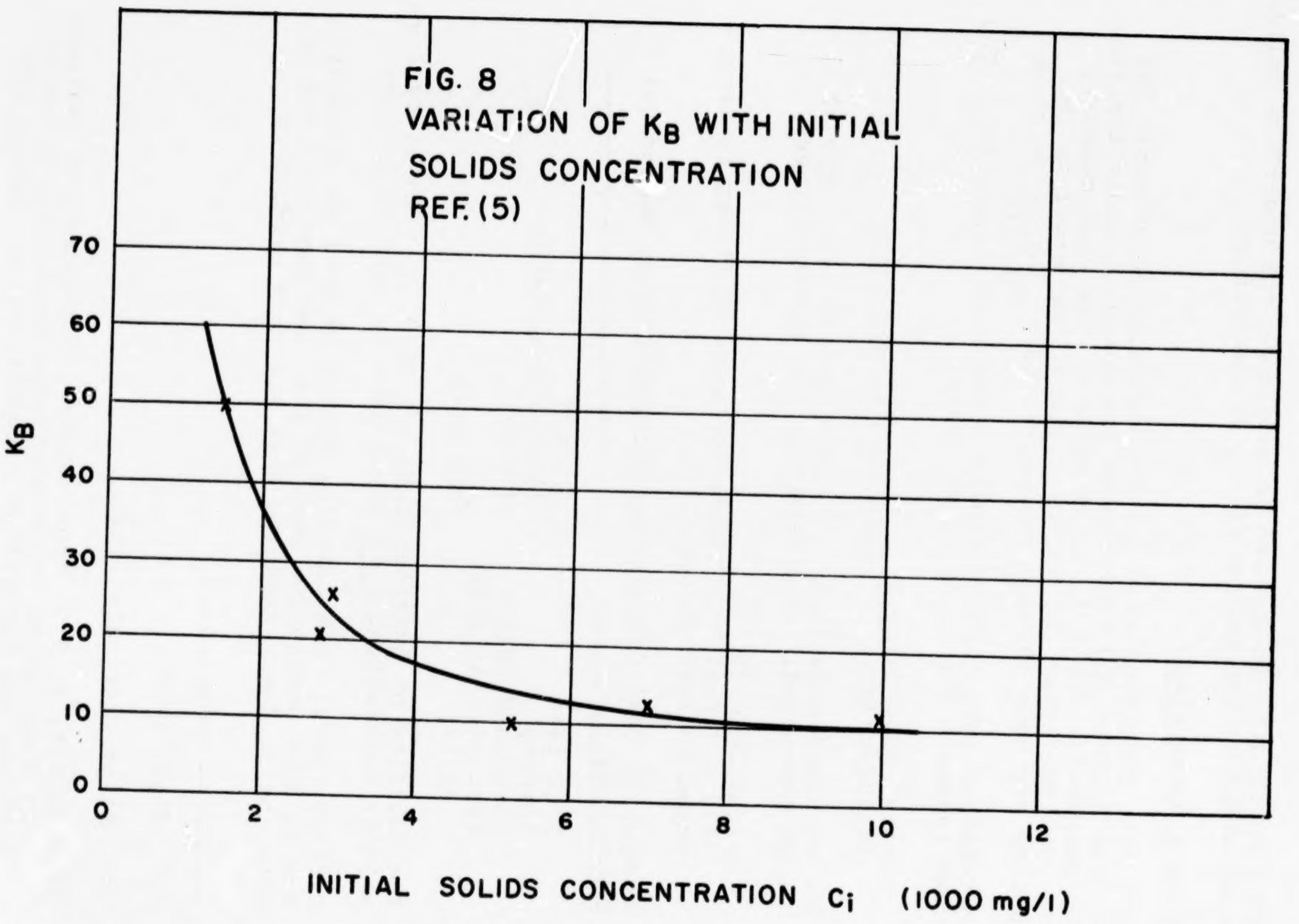


FIG. 8
VARIATION OF K_B WITH INITIAL SOLIDS CONCENTRATION
REF. (5)

This model will be applied to determine the underflow solids discharged to the vacuum filter or centrifuge.

Sludge Dewatering

The cost functions used for the calculation of costs for vacuum filters and centrifuges are based on those applied by Quirck (7) for industrial wastes. The unit capacity or loading factor for vacuum filters, expressed as lb. solids per hour through one square foot $(\frac{\text{lbs/hr}}{\text{sq. ft.}})$ will be determined from experimentally determined values (5). The cost function for centrifuges gives:

Capital Cost ($) = $15{,}700 \times (\text{HP})^{0.40}$ (adjusted to ENR 1285)

The required horsepower is based on 1 HP per 1 gpm of sludge dewatered. Cost function for vacuum filters.

Capital Cost ($) = $4820 \times (\text{area})^{0.58}$ where the area of filter is determined by load factor.

Example of Cost Calculation for Plant Using Mechanical Dewatering

Flow rate	1.0 mgd
Acidity	2000 mg/l as $CaCO_3$
Suspended solids	200 mg/l
Precipitable metal salts	200 mg/l

The basicity of hydrated lime (2) is 0.71. For every 1 gm acidity neutralized $\frac{0.76}{0.71}$ gm of lime is used to produce 1.36 of $CaSO_4$. The basicity factor of 0.71 is probably due to some unreactive part of the lime that will end up with the sludge. Assuming that the main product of neutralization is $CaSO_4$, the concentration of the salt in the effluent will be determined by the solubility product. $(Ca^{++})(SO_4^{=}) = 10 \times 10^{-6}$, thus the molar concentration of $CaSO_4$ in solution would be 0.00315 molar or 428 mg/l. Metal precipitates will add to the sludge as will initial suspended solids. These values are normally not high. Where suspended solids are high, they will be dealt with separately under the cost function. As some metals will precipitate during neutralization, these will be added to the total acidity for the purpose of this study.

---

(2) Rice, ibid

(5) Atlas Chemicals, ibid

(7) Quirck, T. P., "Application of Computerized Analysis to Comparative Costs of Sludge Dewatering by Vacuum Filter and Centrifuge," Report Quirck, Lawler and Matusky Engineers, New York.

Thus, total sludge produced given by sludge (mg/l) =
1.36 x acidity

+0.31 x acidity for unreactive lime constituents
+15% of acidity for metal ppts
-428 mg/l
=1.36 x 2000 + 0.31 x 2000 + 0.15 x 2000 - 428 =
3400 mg/l

Assume sludge production 1.7 x acidity.
Equalization for 6 hours, i.e., basin size 0.25 MG
From cost curve, Capital Cost = \$20,000
Neutralization installation
From Figure 4 Capital Cost = \$54,000
Thickener - clarifier
From Figure 9 Capital Cost = \$110,000
Assume
Underflow solids concentration 2% solids

$$\text{Volume of sludge produced} = \frac{3400 \times 8.33}{0.02 \times 8.13} = 170{,}000 \text{ gal/day}$$

Vacuum filter $\quad L_f = 2.5 \dfrac{\text{lbs/day}}{\text{sq. ft.}}$ based on Ref (7)

$$\text{Filter area} = \frac{3400 \times 8.33}{2.5 \times 16}$$

= 710 sq. ft. for 16 hrs/day operation

$$\text{Capital Cost} = \$4820 \times (710)^{0.58}$$

= \$216,000

Capital Cost of Centrifuge

Sludge volume = 170,000 gpd
= 142 gpm for a 20 hour day

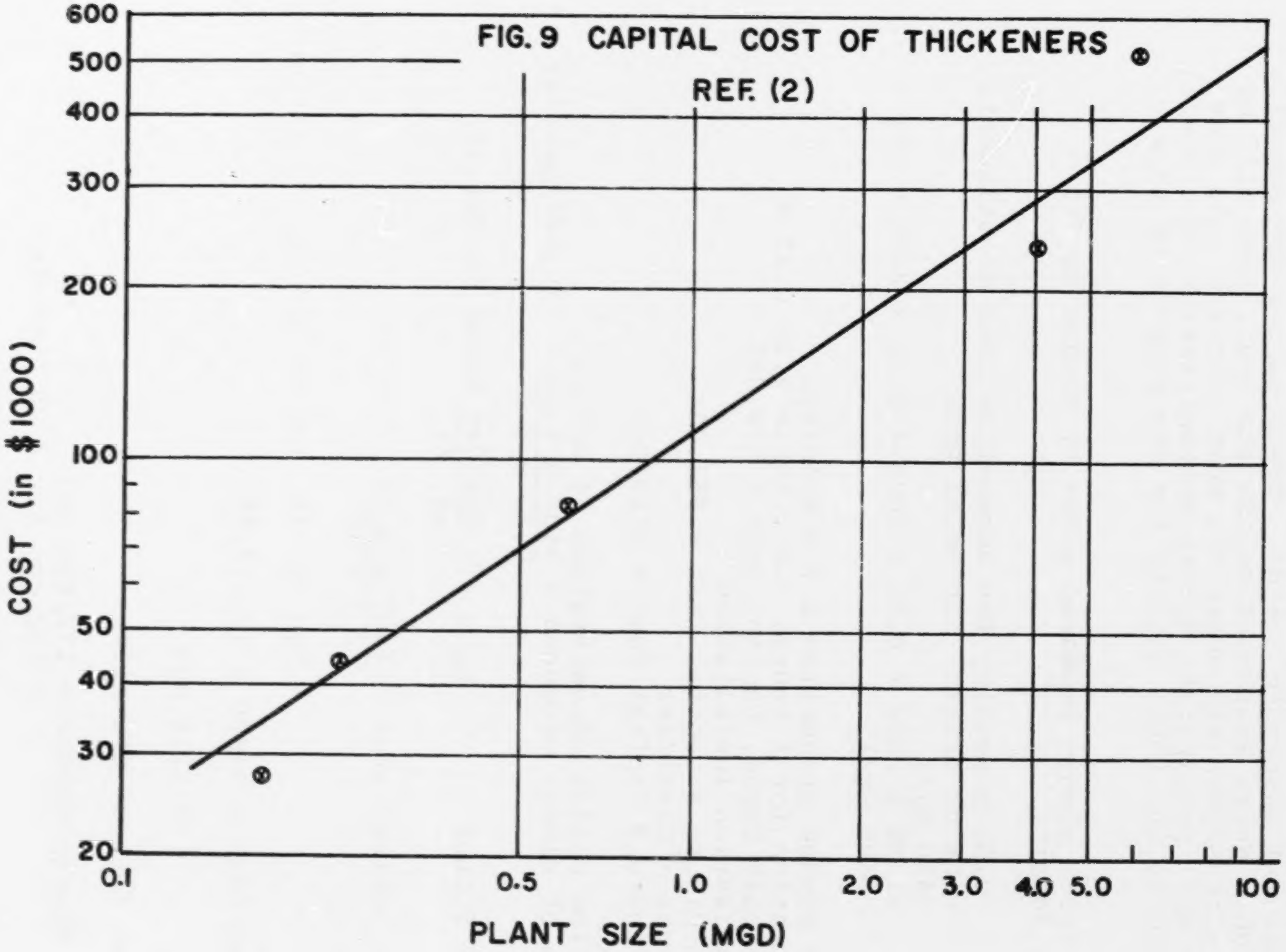


FIG. 9 CAPITAL COST OF THICKENERS ⊗

REF. (2)

which requires 142 HP

$$\text{Capital Cost} = \$15{,}700 \times (142)^{0.40}$$
$$= \$114{,}000$$

The cost of the vacuum filter is much higher than for the centrifuge but there will be a substantial saving in the operating cost as little chemicals will be required to achieve the desired results. The capital cost for vacuum filtration will be used here.

Total cost (excluding trucking)

Equalization	20,000
Neutralization	54,000
Thickener clarifier	110,000
Vacuum filter	216,000
	400,000
Add 35% for site preparation pipework, etc.	140,000
	$540,000

Calculating a range of values for flow Q from 0.5 to 50 mgd and for acidity A from 500 mg/l to 10,000 mg/l, the following cost model was found:

$$\text{Capital Cost (in \$1000)} = 300 \times Q^{0.71}A^{0.34}$$

The acidity seems to be less of a factor in this model but only because trucking or other disposal of the filter cake has been included in the total calculated costs. Also, the operating cost will be much higher than for lagooning of the sludge. Although the capital costs will be lower, the total annual cost for mechanically dewatered sludge will be high.

Operating costs were determined from the acid mine drainage report without sludge disposal and the operating costs of vacuum filters were added to that. The resultant curves are shown in Figure 10.

Suspended Solids

The sludge produced from the lime neutralization process has more definite properties than the sludge produced by the settling of other suspended matter. It was assumed that at worst the suspended solids will have the same properties and for this reason, it was lumped together with acidity in the calculation of total costs.

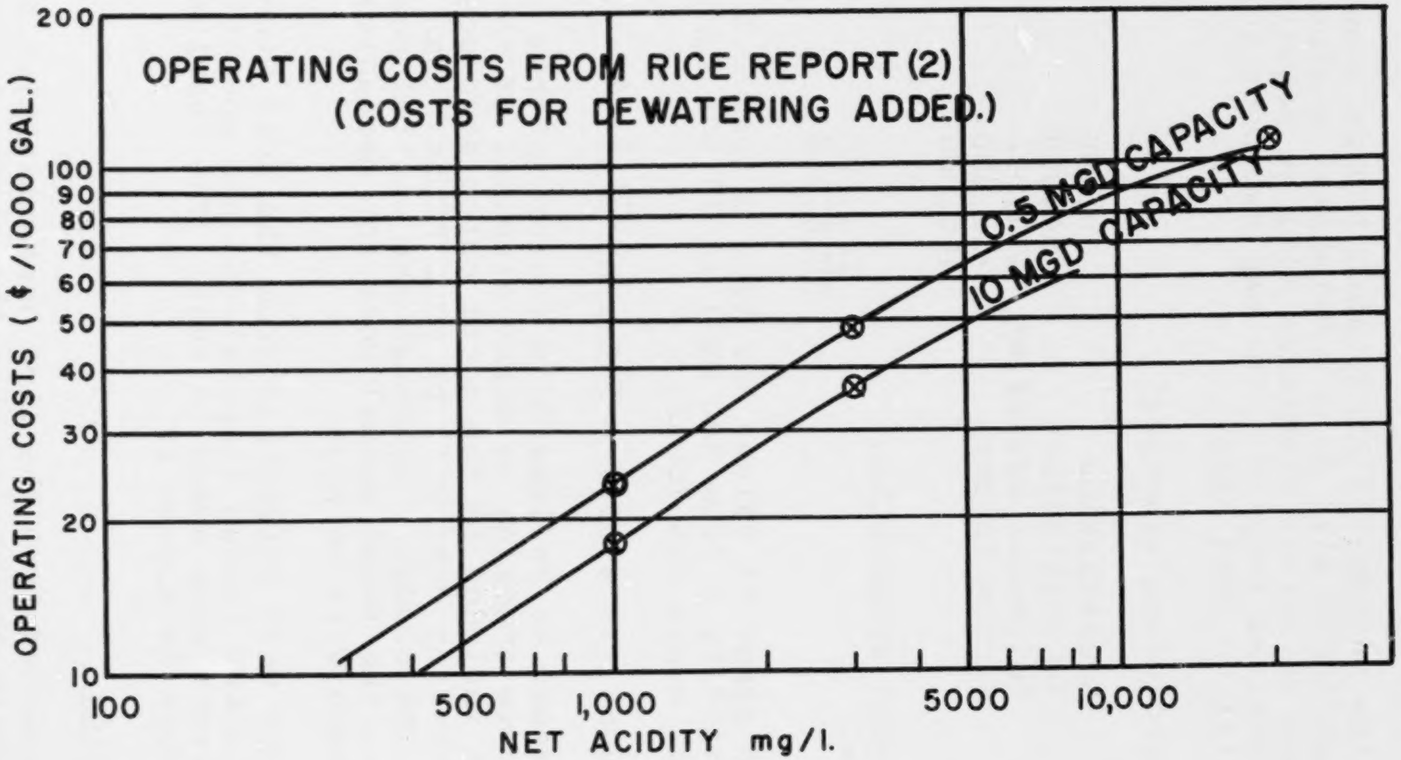


FIGURE 10
OPERATING COSTS FOR LIME NEUTRALIZATION INCLUDING SLUDGE DEWATERING BY VACUUM FILTRATION

Filtration

The cost values used for filtration were obtained from Smith's (8) curves and they are reproduced in Figure 11. The capital costs and operating costs were calculated at ENR index 1285.

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(8) Smith, R., "Cost of Conventional and Advanced Treatment of Wastewater, Journal Water Pollution Control Federation, Vol. 40, 69, September, 1968.

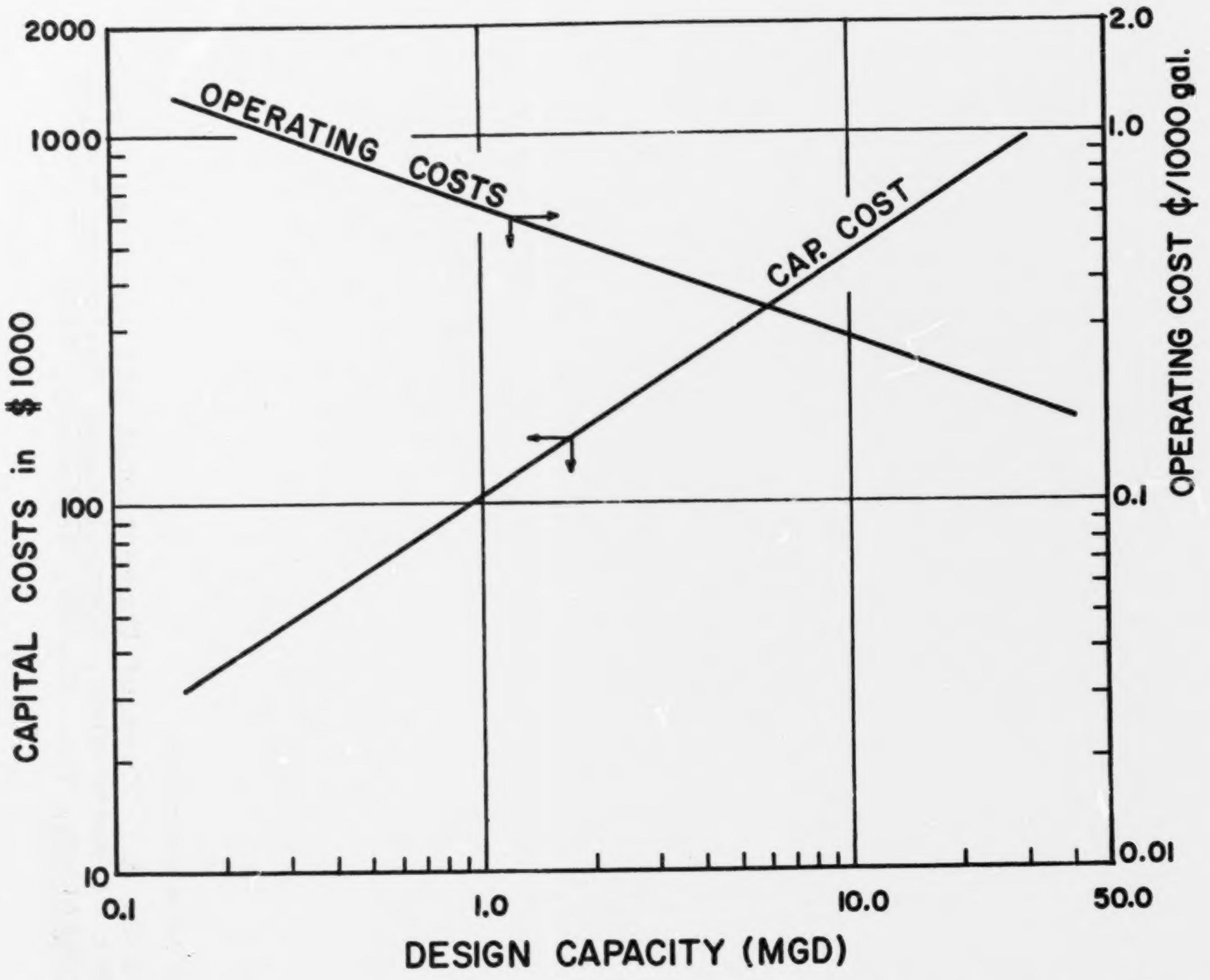

FIGURE II. COST OF FILTRATION THROUGH SAND OR GRADED MEDIA AFTER SMITH (8)

DEEP WELL DISPOSAL

The capital cost and operating cost for deep well injection systems are presented in the attached Figures 12 and 13. These costs are presented for different flow rates as well as casing head pressures. The capital costs are expressed in terms of total capital investment and the operating cost is expressed on an annual basis. In order to develop usable curves, it is necessary to select typical geological and hydraulic systems (9). Therefore, the following items were constant:

Depth
Effective Thickness
Porosity
Permeability
Reservoir Pressure of the Disposal Horizon

The diameter of the injection stream was also held constant and for this particular example was seven inches. The geological characteristics assumed were based on evaluation of existing data and are valued to represent the conditions at more than 50 percent of the existing installations. The operating costs are based on a power cost of 0.005 dollars per kilowatt hour, an interest rate of five percent and a payout period of 20 years.

The ENR building cost index of 700 was used for estimating the capital cost. These cost flows include minimal service treatment. If service treatment greater than filtration is required, the cost of the additional unit process must be added to the capital and operating cost shown in Figures 12 and 13.

In order to convert costs to 1969 values with ENR index 1285, the values from the curve were multiplied by 1.84.

---

(9) Moseley, J. C., and J. F. Malina, Jr., "Relationships Between Selected Physical Parameters and Cost Responses for the Deep-Well Disposal of Aqueous Industrial Wastes," Report published by the Center for Research in Water Resources, Technical Report, EHE-07-6801, CRWR-28, The University of Texas at Austin, (August, 1968).

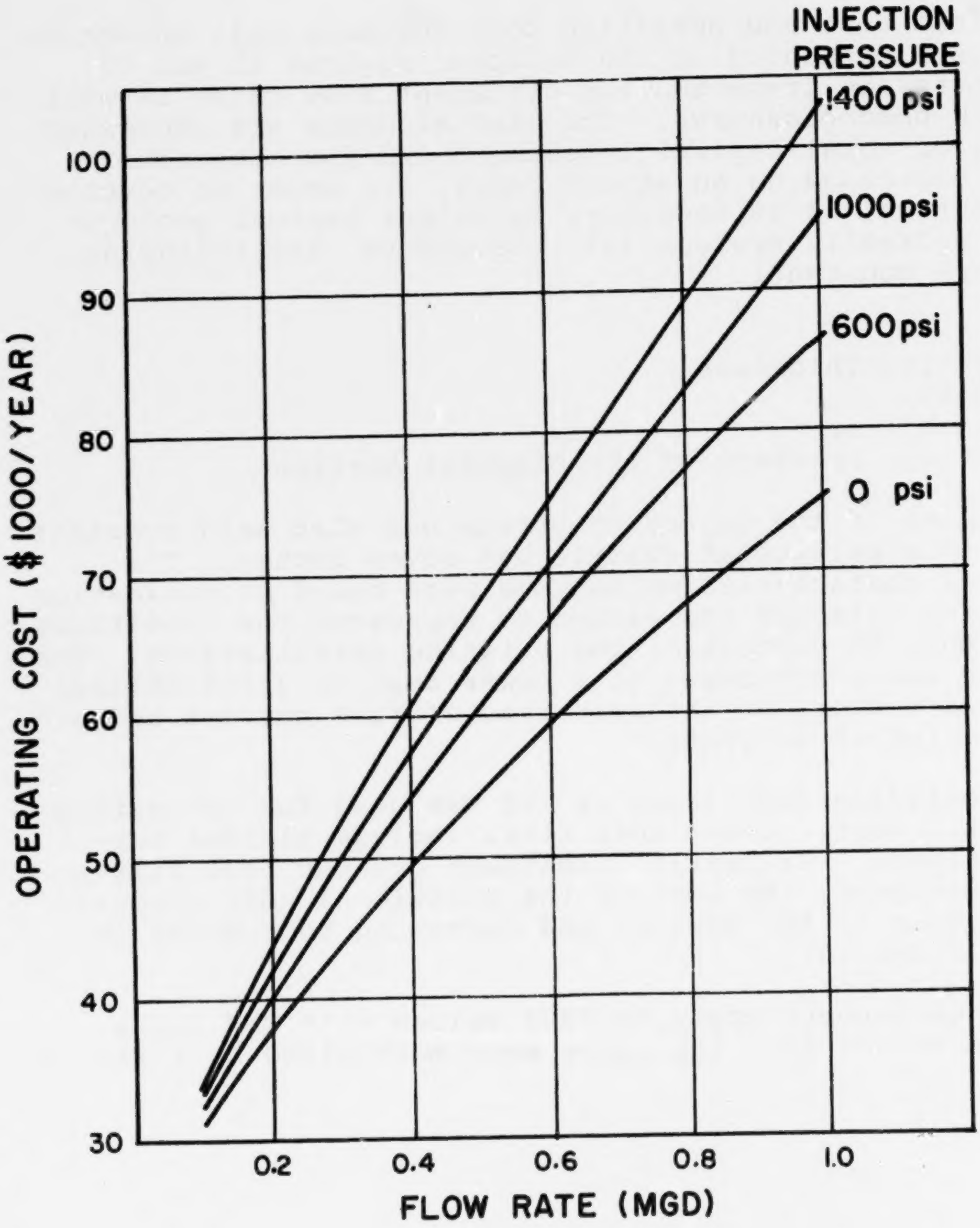

FIG. 12

ANNUAL OPERATING COST OF DEEP WELL INJECTION SYSTEMS FOR WASTE DISPOSAL

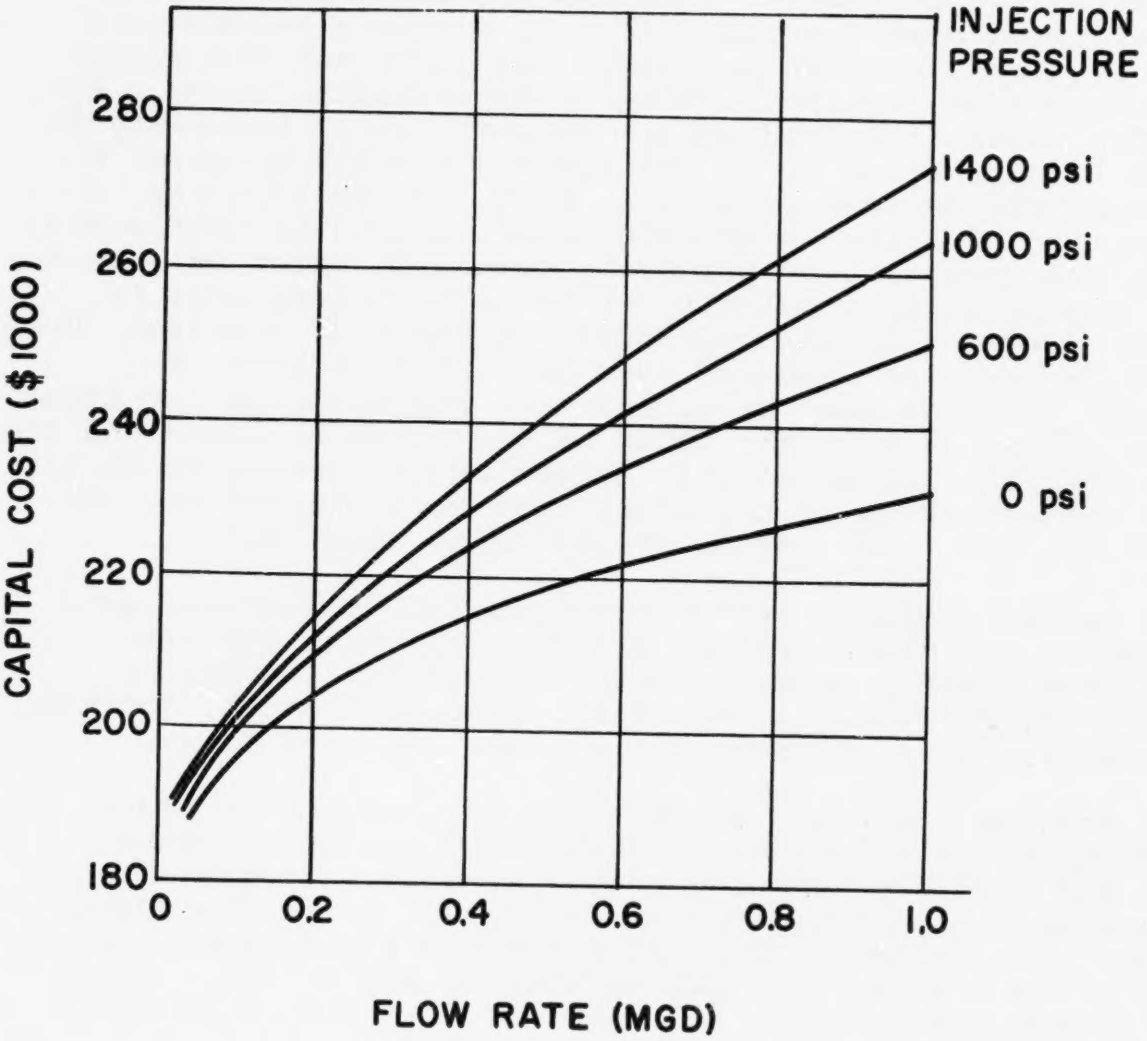

FIGURE 13
CAPITAL COST OF DEEP WELL
INJECTION SYSTEMS FOR
WASTE DISPOSAL

REVERSE OSMOSIS

The curves actually used for cost calculation were obtained from the Acid Mine Drainage Report (2) and they are reproduced in Figures 14-17. The pretreatment and brine disposal required was considered separately. These curves gave generalized cost figures. If more accurate assessments are required, one can calculate the yield and the actual membrane size required. This is demonstrated below. For a high total dissolved solids content, it is necessary to make an assumption as to the number of units required to produce the desired effluent. Also, the feasibility of rejection of brine at certain levels should be considered. From the viewpoint of producing palatable water only, one may reject a large quantity of brine for every unit of water produced if brine disposal presents no problem. However, when brine disposal does present a problem, the amount produced must be minimized. For disposal for treatment purposes, both the value of the water produced and the cost of brine disposal will determine the degree to which the concentration of the brine must be increased or, conversely, the total volume of the brine decreased.

The curves (Figures 14-16) were plotted from actual data of pilot and demonstration plants. The membrane area required depends on many factors including: membrane characteristics (salt rejection, porosity, etc.), applied pressure, water characteristics, and the feed flow.

The capital costs quoted here are for the entire plant including installation. However, the operating costs are for power consumption only. Membrane replacement costs have been estimated at $0.35/1000 gal. of product flow. The estimated overall projected figure would be .35 + .98 = $1.33/1000 gal of treated water (10). This is a very conservative estimate and does not consider future improvements in membrane technology.

The operating costs do not include pretreatment to remove undesirable pollutants such as iron, manganese, organics, etc., and do not consider ultimate disposal of the brine.

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(2) Rice, ibid

(10) Spiegler, K. S., Principles of Desalination, Academic Press, (1966).

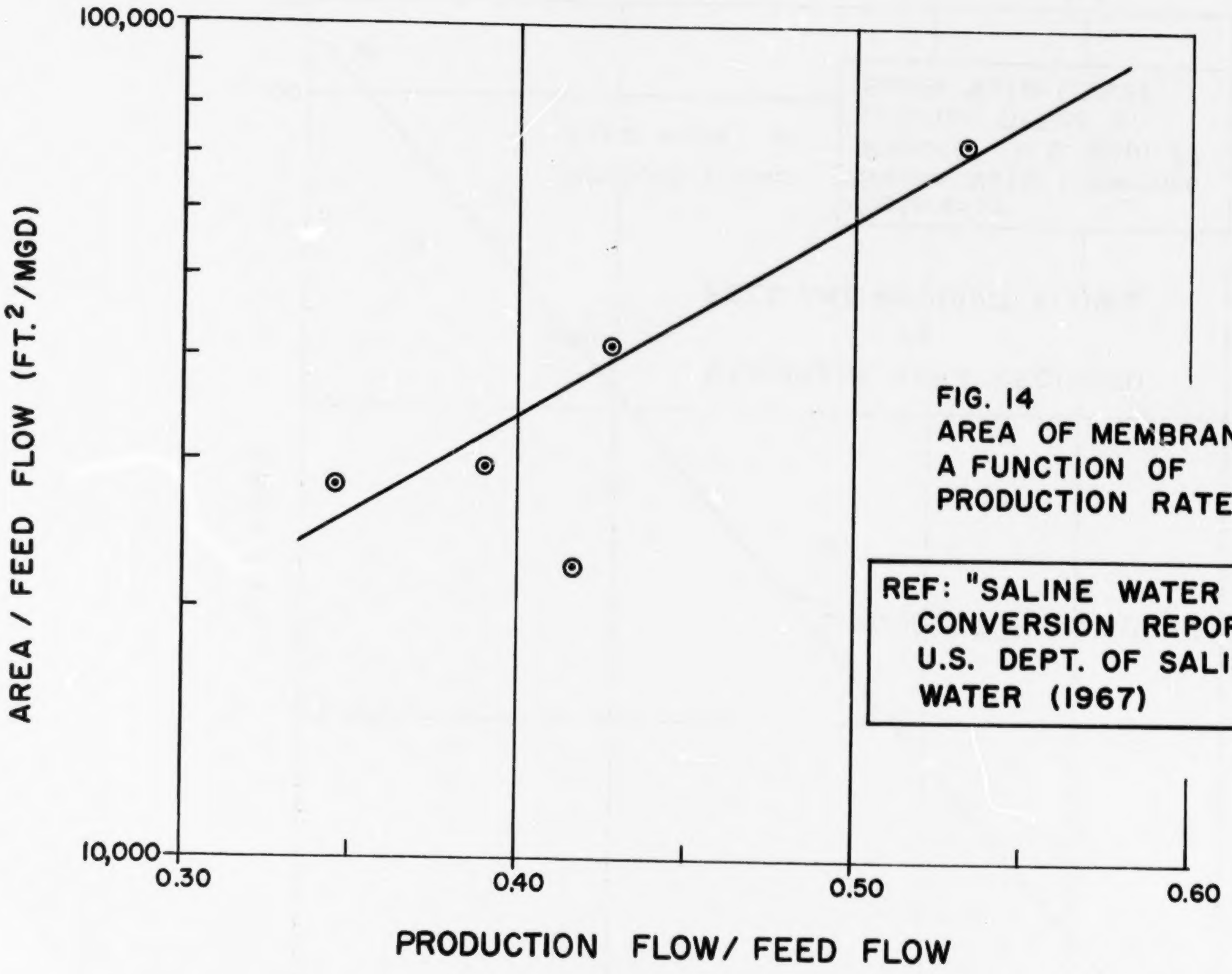
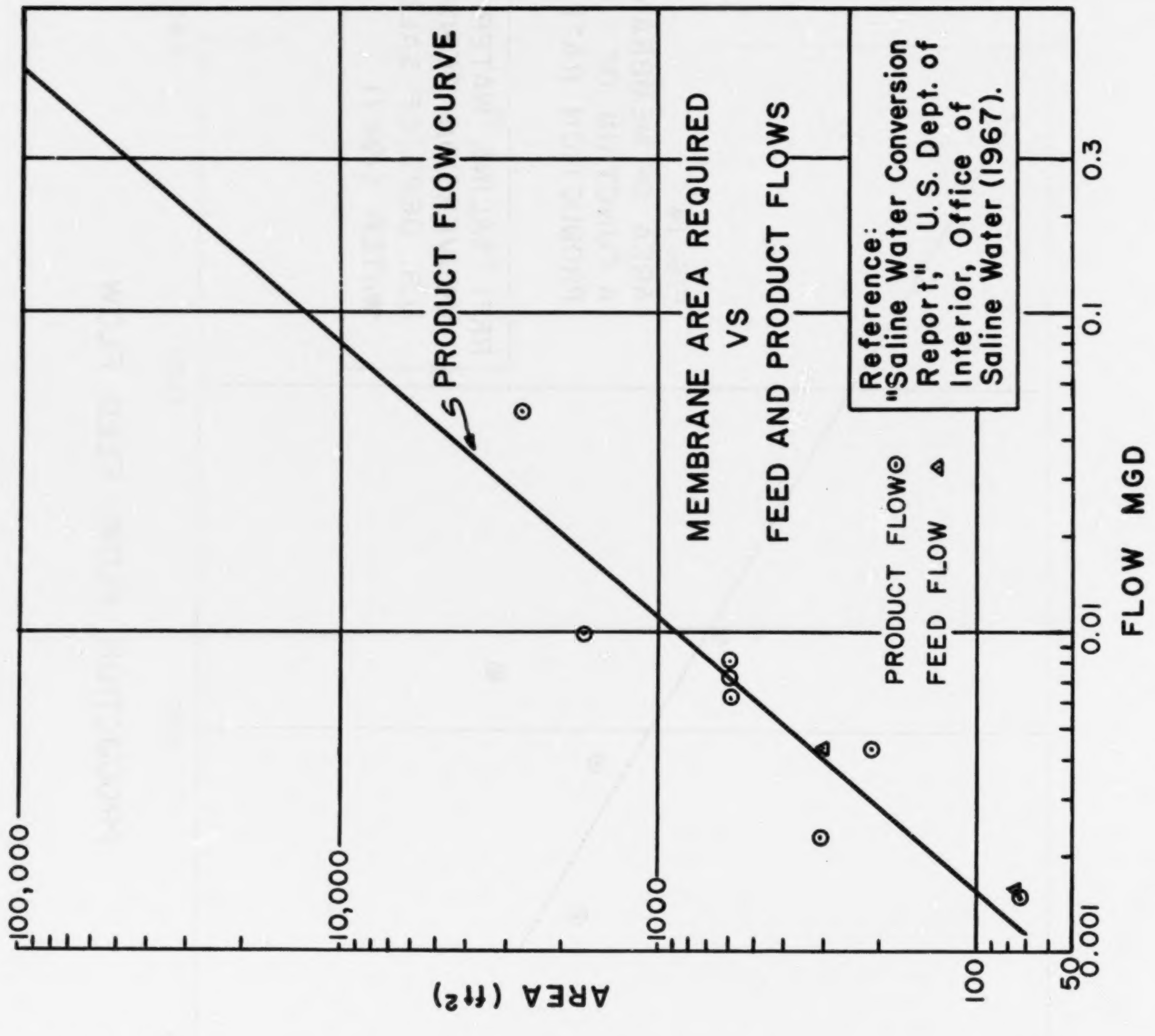


FIG. 14
AREA OF MEMBRANES AS A FUNCTION OF PRODUCTION RATE

REF: "SALINE WATER CONVERSION REPORT," U.S. DEPT. OF SALINE WATER (1967)

FIGURE 15



MEMBRANE AREA REQUIRED VS FEED AND PRODUCT FLOWS

Reference: "Saline Water Conversion Report," U.S. Dept. of Interior, Office of Saline Water (1967).

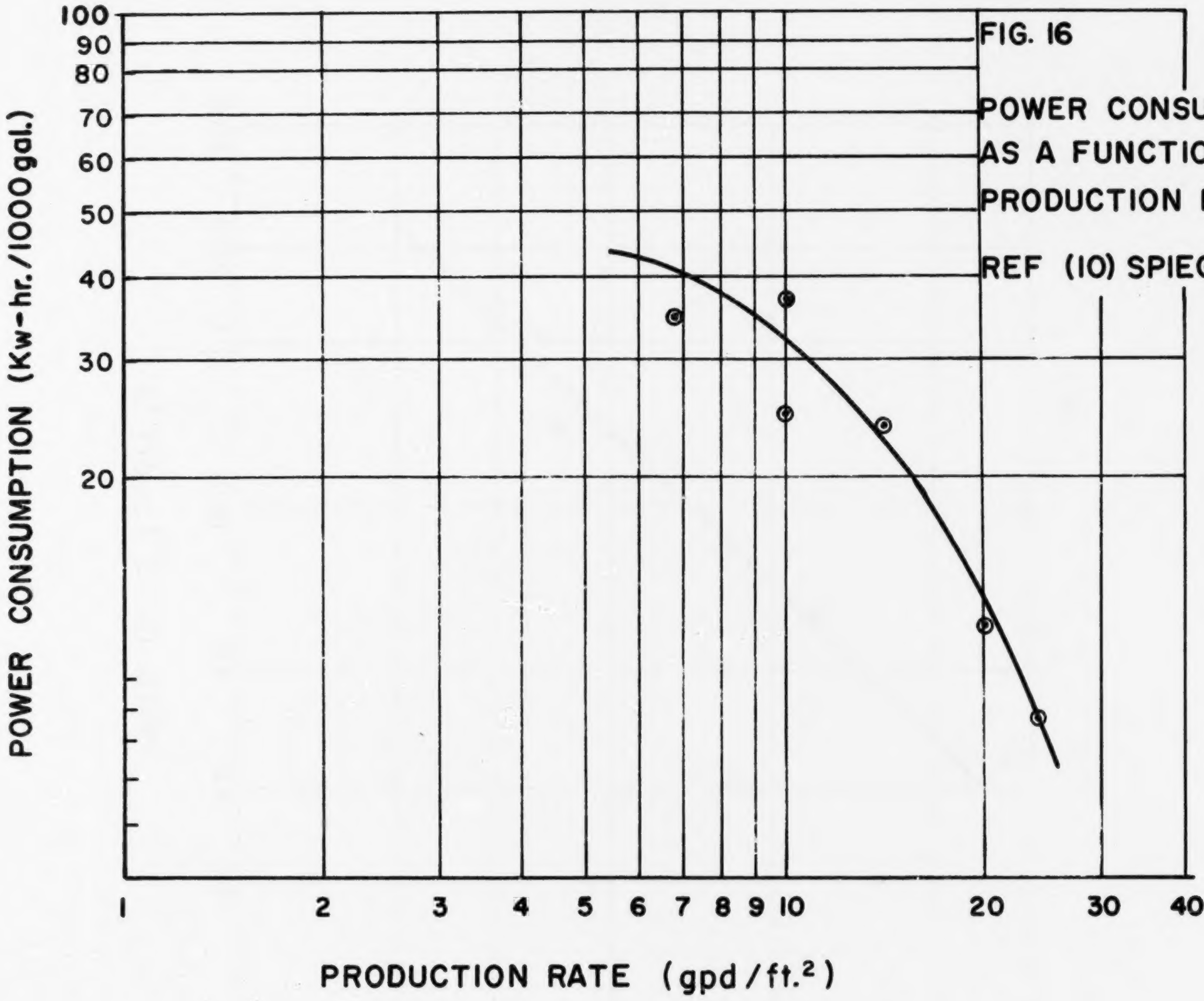
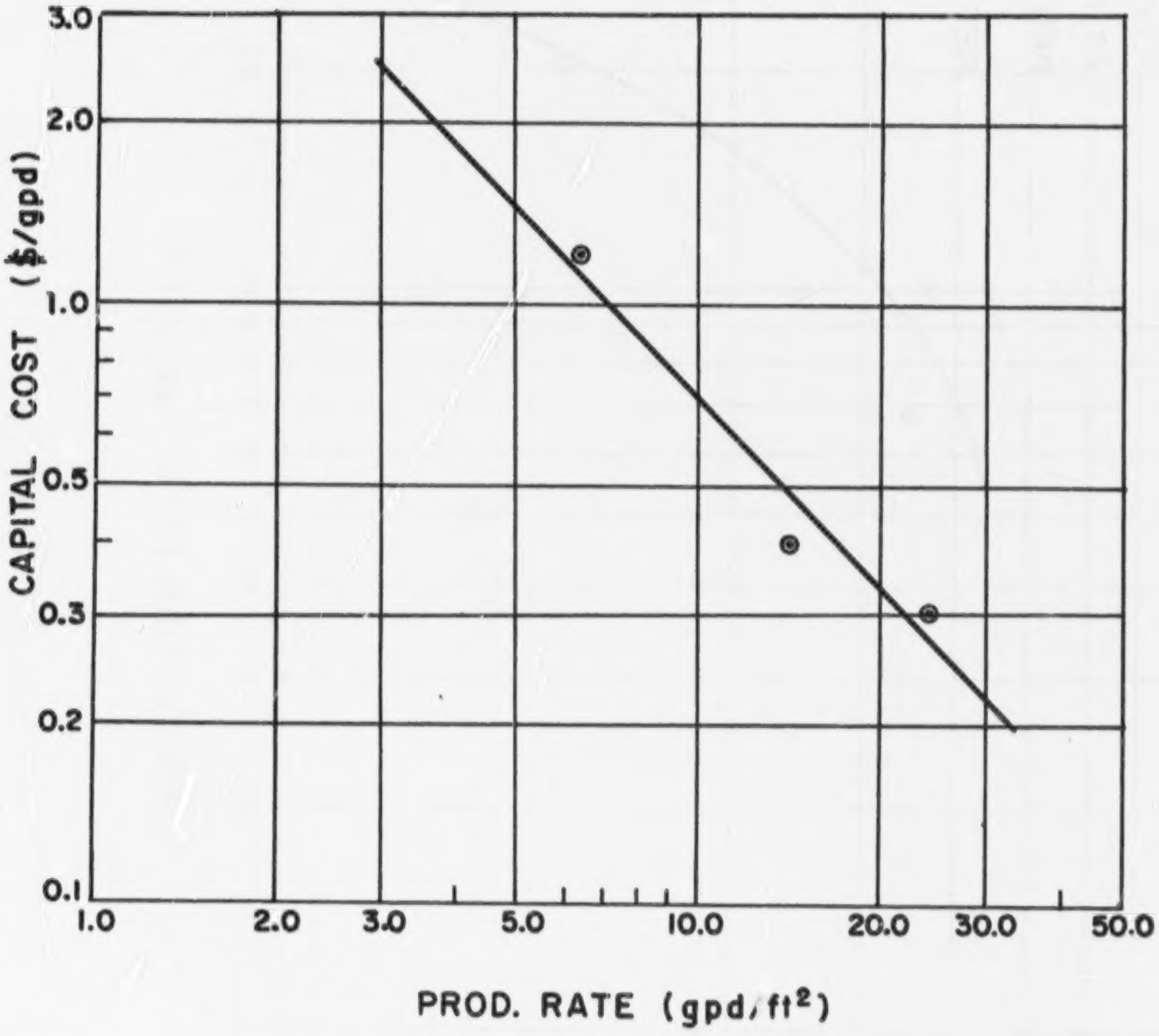


FIG. 16

POWER CONSUMPTION AS A FUNCTION OF PRODUCTION RATE.

REF (10) SPIEGLER, ibid

FIG. 17
CAPITAL COST AS A FUNCTION OF PRODUCTION RATE
REF. (10) SPIEGLER, ibid



The latter was considered separately for calculating the cost of treatment.

Most work with reverse osmosis has been concerned with TDS levels of 1000-5000 mg/l. Thus, the plots presented are based on these ranges. Higher levels of TDS would probably require much more specific surface for equivalent removals, thus increasing capital expenditures. Also, maintenance costs would be increased due to increased scaling, etc.

I. REQUIRED DATA: Plant Flow, Removal Desired Production Flow (amount of plant flow to be recovered through membrane)

If plant flow = 1 mgd and a recovery factor of 60% is desired, then the production flow = 600,000 gpd = 0.60 mgd waste flow = 0.40 mgd

At influent concentration of 5000 mg/l TDS and a desired effluent of 500 mg/l, the desired removal or fractional "cut" would be 0.90.

II. SIZE OF PLANT AND POWER CONSUMPTION

Product flow = 0.60 mgd
Prod/Feed = 0.60
From Figure 14: Area/Feed flow = 102,000 ft^2/mgd
∴ Total Area = 102,000 ft^2
check: From Figure 15: @ Prod. Flow = 600,000 gpd,
Area = 102,000 ft^2
Production rate = 600,000/100,000 = 6.0 gpd/ft^2
From Figure 16: Power = 44 KW-hr/k gal = 44,000 KW - hr/day

III. COSTS

Capital Cost

Production rate = 5.0 gpd/ft^2
∴From Figure 17:
Capital Cost = 1.20 \$/gpd + 10^6 gpd

Operating Cost

Power Consumption = 44,000 kw-hr/day (Figure 16)
∴@ \$0.015/kw-hr
Power Cost = \$660/day

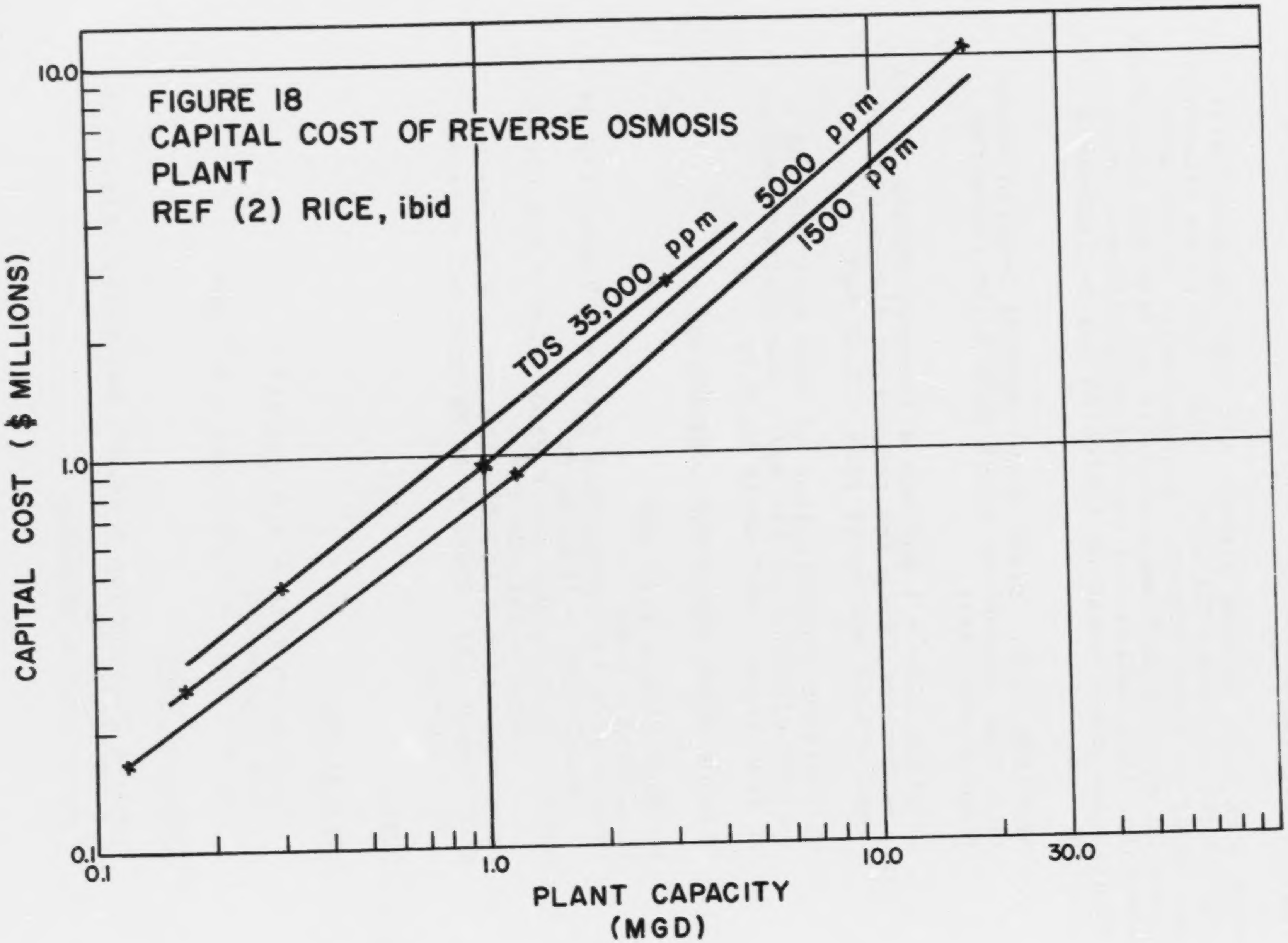


FIGURE 18
CAPITAL COST OF REVERSE OSMOSIS
PLANT
REF (2) RICE, ibid

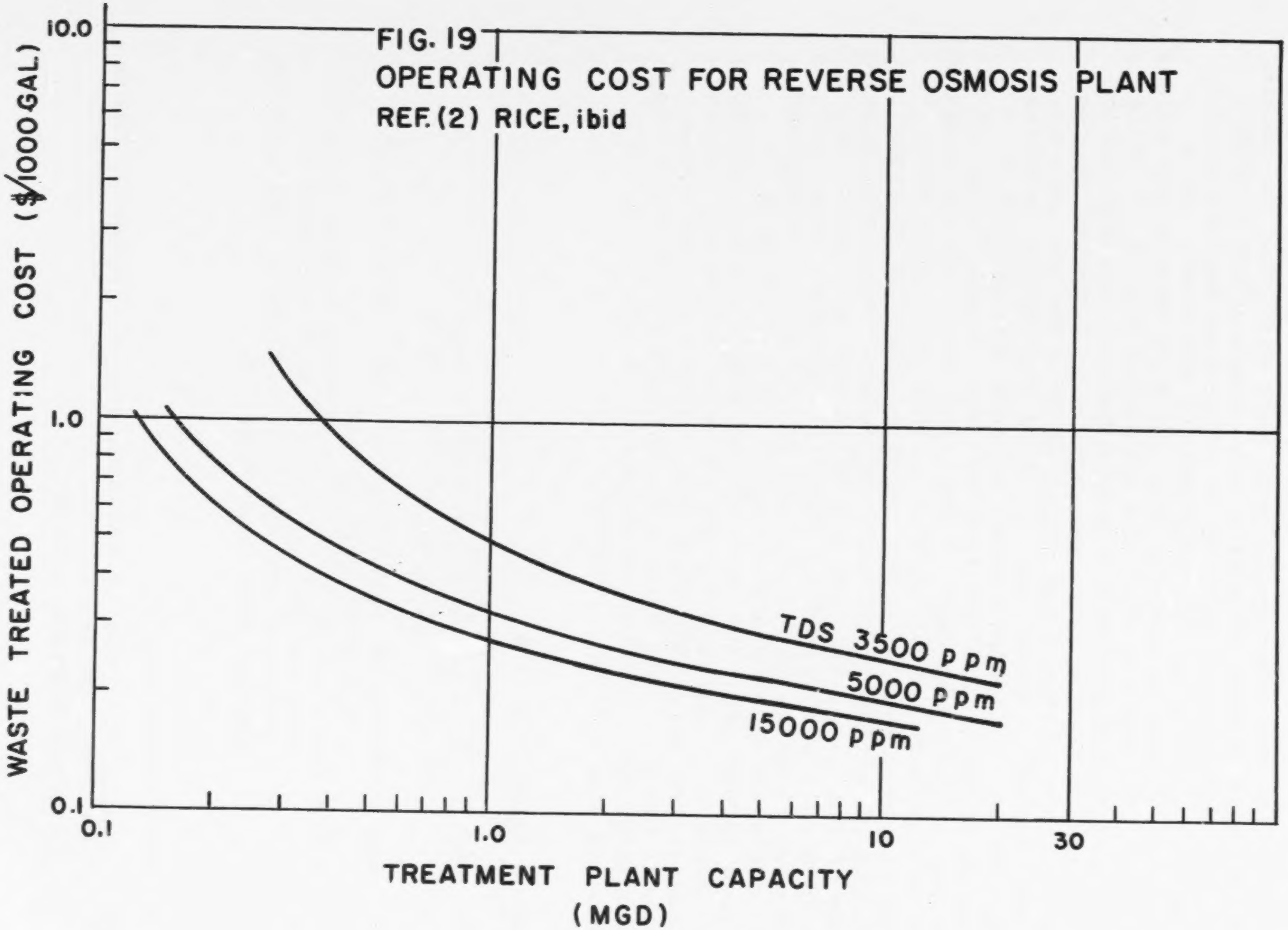


FIG. 19
OPERATING COST FOR REVERSE OSMOSIS PLANT
REF. (2) RICE, ibid

ELECTRODIALYSIS

Cost figures for electrodialysis were difficult to obtain because this method is mostly used where brine disposal does not represent a problem or very high concentrations of effluent brine or not necessarily required. As a treatment method to concentrate and thus reduce the volume of brine produced, a slightly increased number of cells will have to be used and a proper balance between brine produced and usable water production will depend on the need or cost of the clean water as well as the cost of brine removal. To get some idea of the number of units required to concentrate waste streams and produce a product effluent of less than 500 mg/l total dissolved solids, a study was made of existing data (11) to produce the set of curves in Figure 20. This will give some idea of the number of units required and the relative amounts of effluent and brine produced. With recirculation of the waste through the cells the concentration in each cell will reach an equilibrium value which is not easy to calculate. Certain values were assumed and the units calculated according to this. Using basic design parameters, the size of the plant was calculated for waste with varying values of total dissolved solids. These values were then used for calculating the final capital costs. From Figure 22, the volume of brine was calculated and the cost of disposal of the brine was added to the cost of treatment.

Design Equations

$$\text{I.}\quad nAp = \frac{1000\ Fd\ F(2K_2C_{d_i}f + K_1Z)}{CE\ (i/Cd)_o(2K_2C_{d_i}\ (1-f) + K_1{}^Y)}$$

nAp = effective transfer area, cm^2 (n=number of individual cell pairs)

f = fraction of total cut through filter (the TDS removal factor) (measure of approach to polarization and film diffusion limitations) should stay less than 0.5

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(11) Electrodialysis in Advanced Waste Treatment, FWPCA Publ. No. WP-20-AWTR-8. Water Pollution Control Research Service (1967).

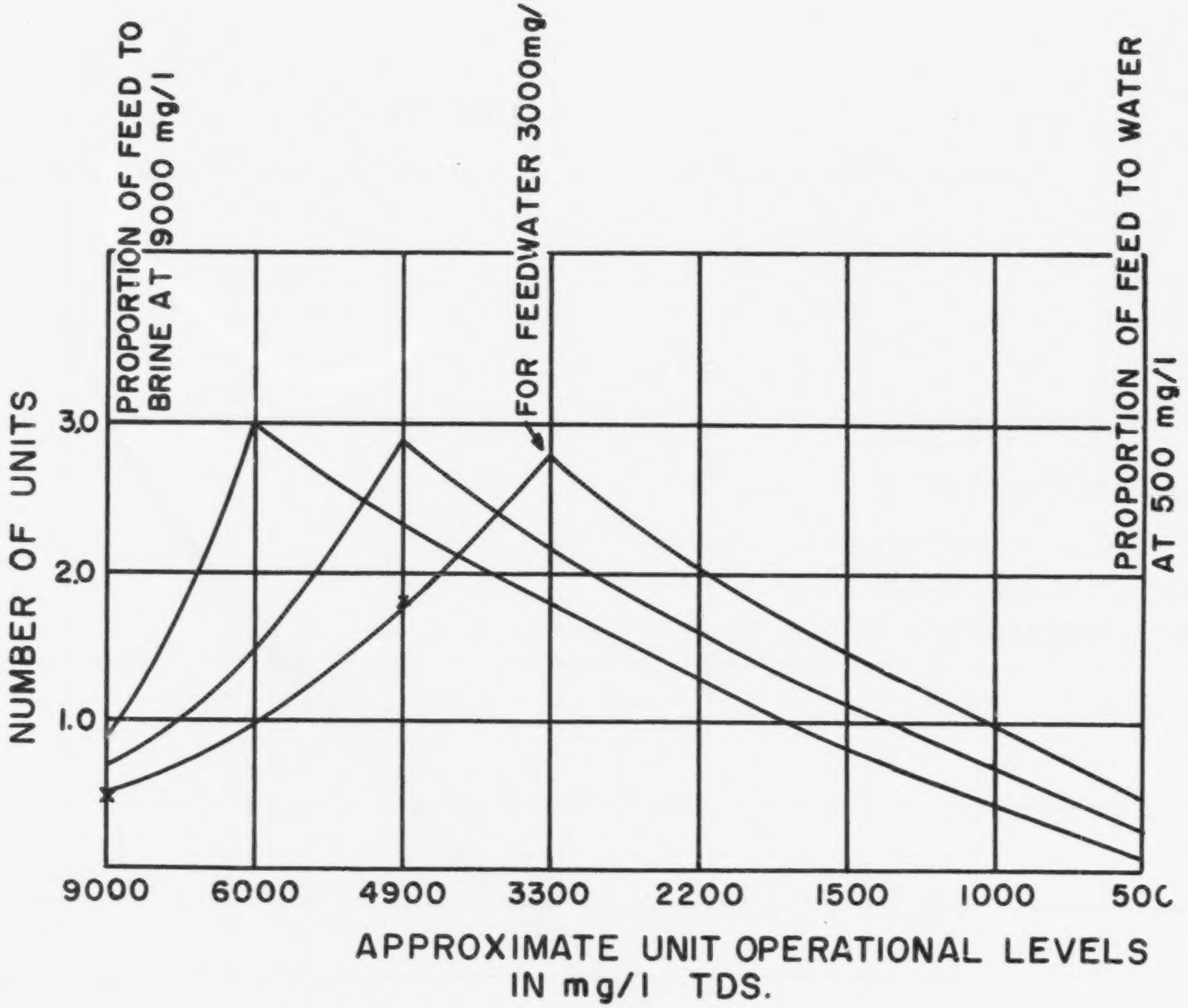


FIGURE 20
DETERMINATION OF TOTAL NUMBER OF UNITS REQUIRED FOR TREATMENT

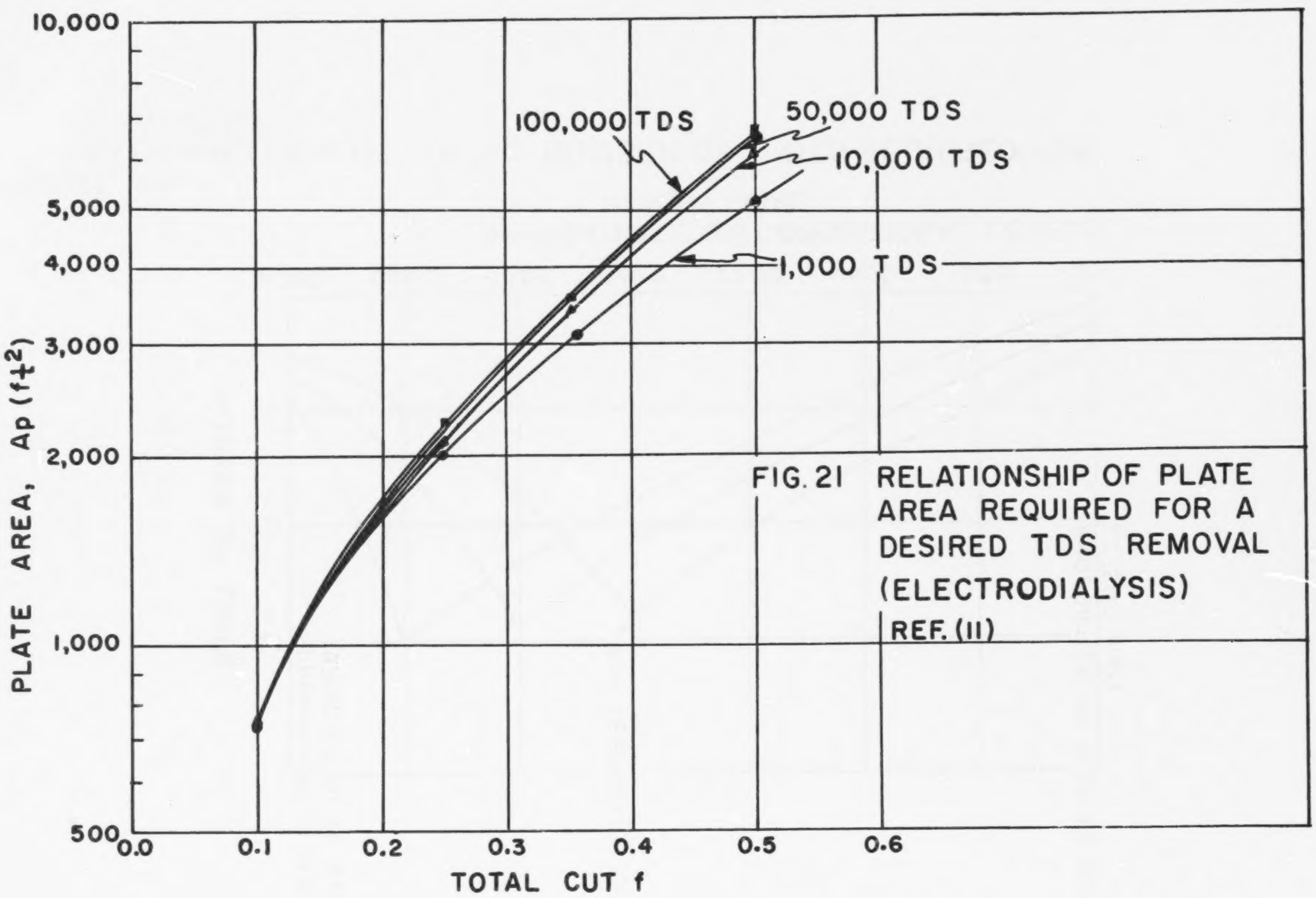


FIG. 21 RELATIONSHIP OF PLATE AREA REQUIRED FOR A DESIRED TDS REMOVAL (ELECTRODIALYSIS) REF. (11)

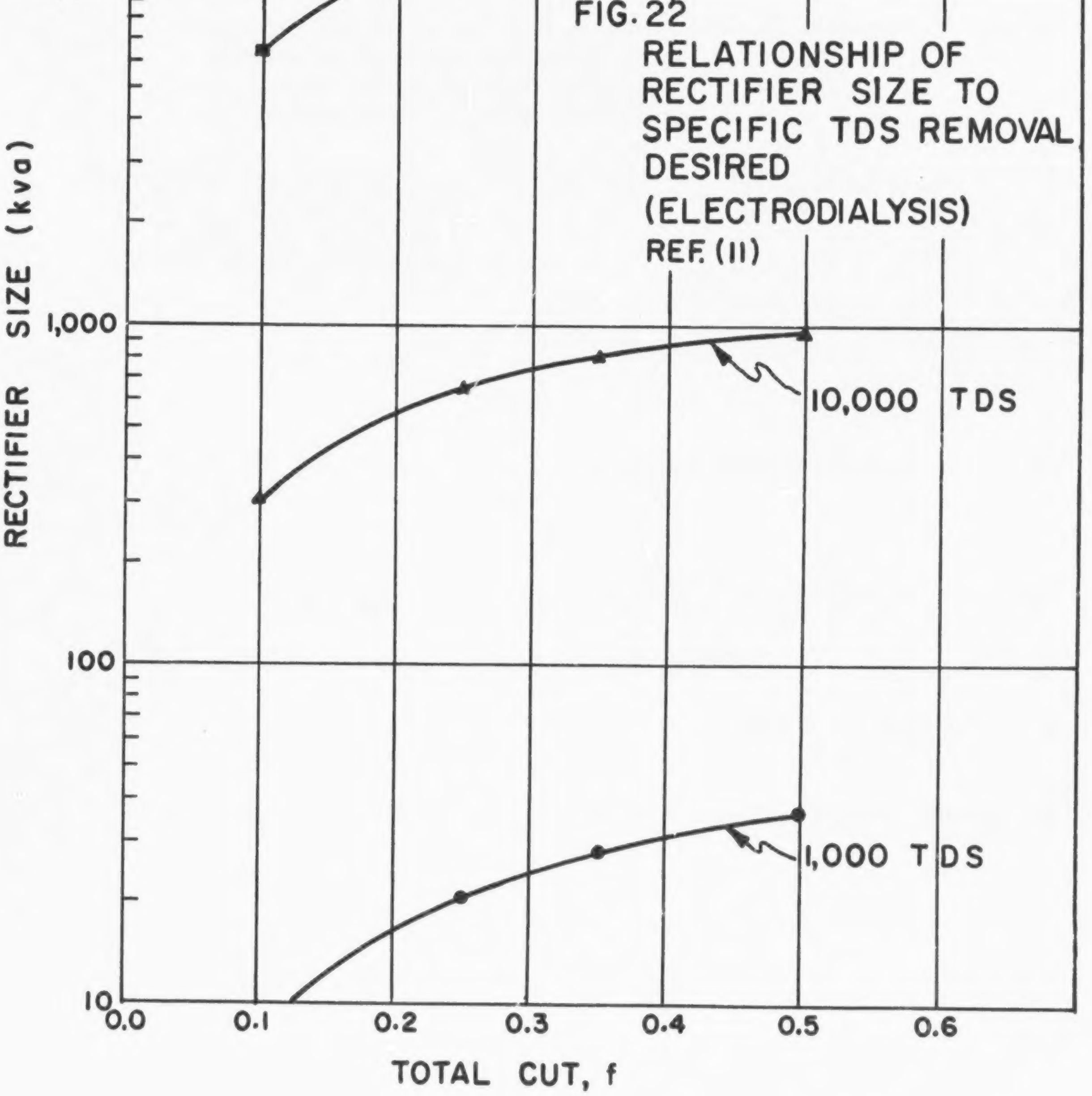


FIG. 22
RELATIONSHIP OF RECTIFIER SIZE TO SPECIFIC TDS REMOVAL DESIRED
(ELECTRODIALYSIS)
REF. (11)

$= (Cd_i = Cd_e)/Cdi$

F = Faraday's constant, 96,500 coulombs/equivalent

i = current density, ma/cm^2

F_d = influent dilute stream flow rate, liters/sec

Cd_i = influent dilute stream concentration, equivalent/liter

Cci = concentrated stream concentration equivalent/liter

k_1, k_2 = constants depending on various membranes, solutions, and temperature parameters
k_1/ca = a solution resistance term
k_2 = a membrane resistance term

$Y = 1 + \frac{(1-f)g}{(gf+1)}$ $(i/Cd)_o$ = a measure of approach polarization. Thus, there is an upper limit to this ratio.

$Z = \ln \frac{(1+gf)}{(1-gf)}$

$g = Cd_i/C_{ci}$

CE = current efficiency

II. $V_p = \frac{(i/Cd)o}{1000} \quad (\frac{K1}{2} (Y + K2\ (1-f)\ Cdi))$

V_p = potential drop across membranes, volts

$I = \frac{Fd\ F\ f\ Cdi}{nCE}$

DC power requirement = P = $(V_p I)$ in kva

TABLE I

SUMMARY

Influent TDS	f	Plate Area (ft^2)	DC Energy (kw-hr)	ED Unit Cost $	Rectifier Cost	Operating Cost DC Energy Cost $/MGD
1,000	0.50	5,180	988	45,380	2,500	9.88
	.35	3,110	742	27,160	1,875	7.42
	.25	2,038	553	17,830	1,400	5.53
	.10	731	235	6,400	595	2.35
10,000	0.50	6,120	26,200	53,600	66,100	262
	.35	3,440	21,600	30,140	54,600	216
	.25	2,177	17,800	19,040	45,000	178
	.10	742	8,220	6,480	20,800	82
50,000	0.50	6,560	494,000	57,450	1,250,000	4,940
	.20	1,678	307,000	14,690	776,000	3,070
	.10	745	171,000	6,503	431,000	1,710
100,000	0.50	6,640	1,890,000	58,150	4,770,000	18,900
	.35	3,585	1,710,000	31,410	4,330,000	17,100
	.25	2,270	1,450,000	19,860	3,550,000	14,050
	.10	747	649,000	6,531	1,641,000	6,490

Example: 10 mgd plant
TDS = 1000 mg/l
Normality = 0.01 equiv./liter

Allowable effluent concentration = 600 mg/l

∴ f = 1000 - 600/1000 = 0.40

Capital Considerations

From Figure 21: Area of plates
= 3,700 ft^2/mgd + 10 mgd
= 37,000 ft^2 total

From Figure 22: Rectifier size
= 30.25 ku-a/mgd + 10 = 302.5 ku-a

From Figure 23: Capital cost of plates, spacers, membranes and electrodes
= 31.500/mgd
= $315.000 total

From Figure 24: Capital cost of rectifier
= $2100/mgd + 10 mgd
= $21,000 total

Capital Cost = $315,000 + $21,000 =	$336,000
Stack hardware = $500/mgd =	5,000
10% installation = 0.10 (341,000) =	3,410
Auxiliary equip. (installed @ 40%) pumps, valves and fittings, control panels, acid tanks, conduct = 20.000/mgd = (10% miscellaneous included)	200,000
Total 1/	$544,400

1/ exclusive of building, spare parts, etc.

Operating Conditions

From Figure 25: DC Energy Requirements
= 840 kw-hrs/mgd
= 8400 kw-hrs

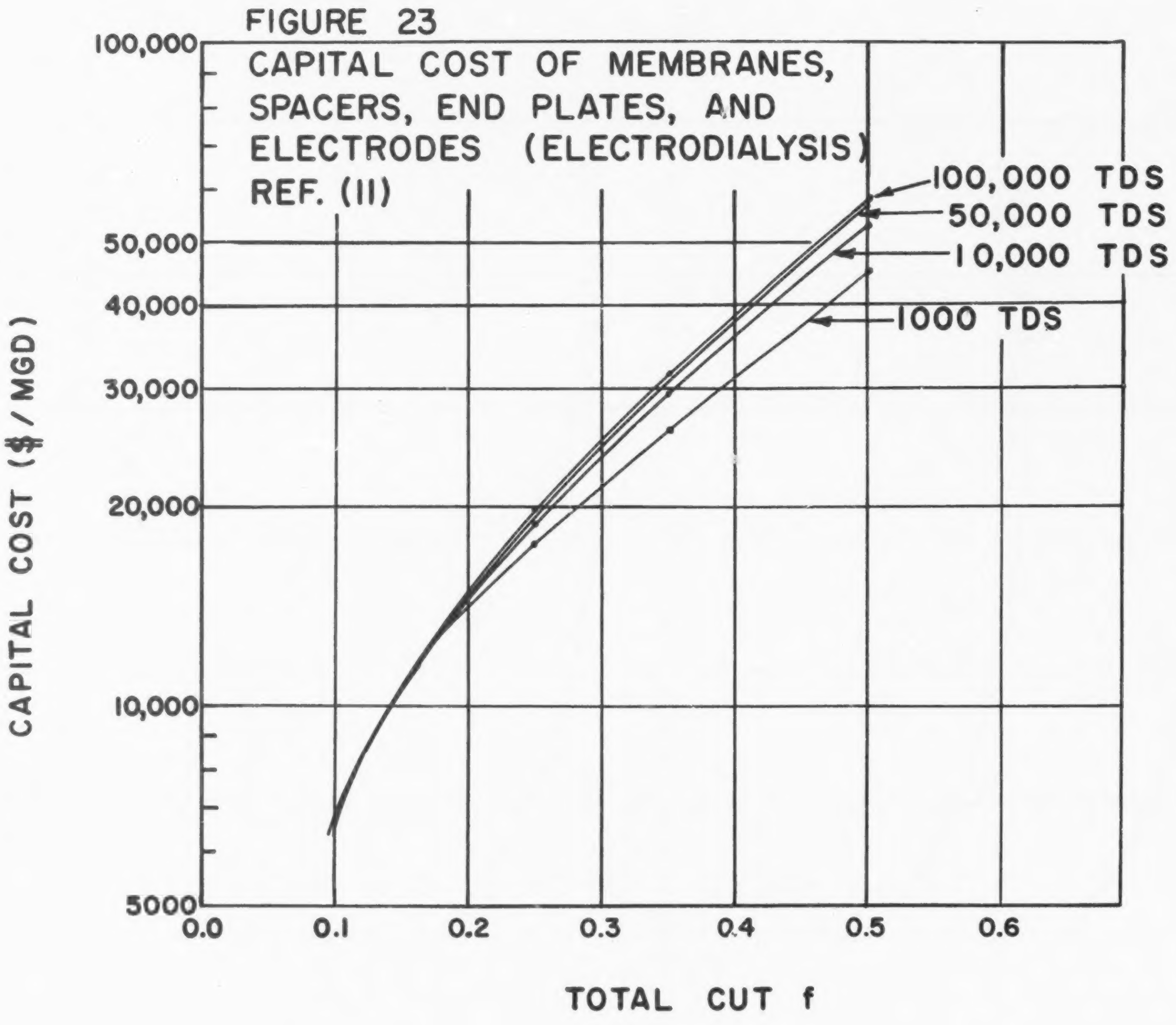
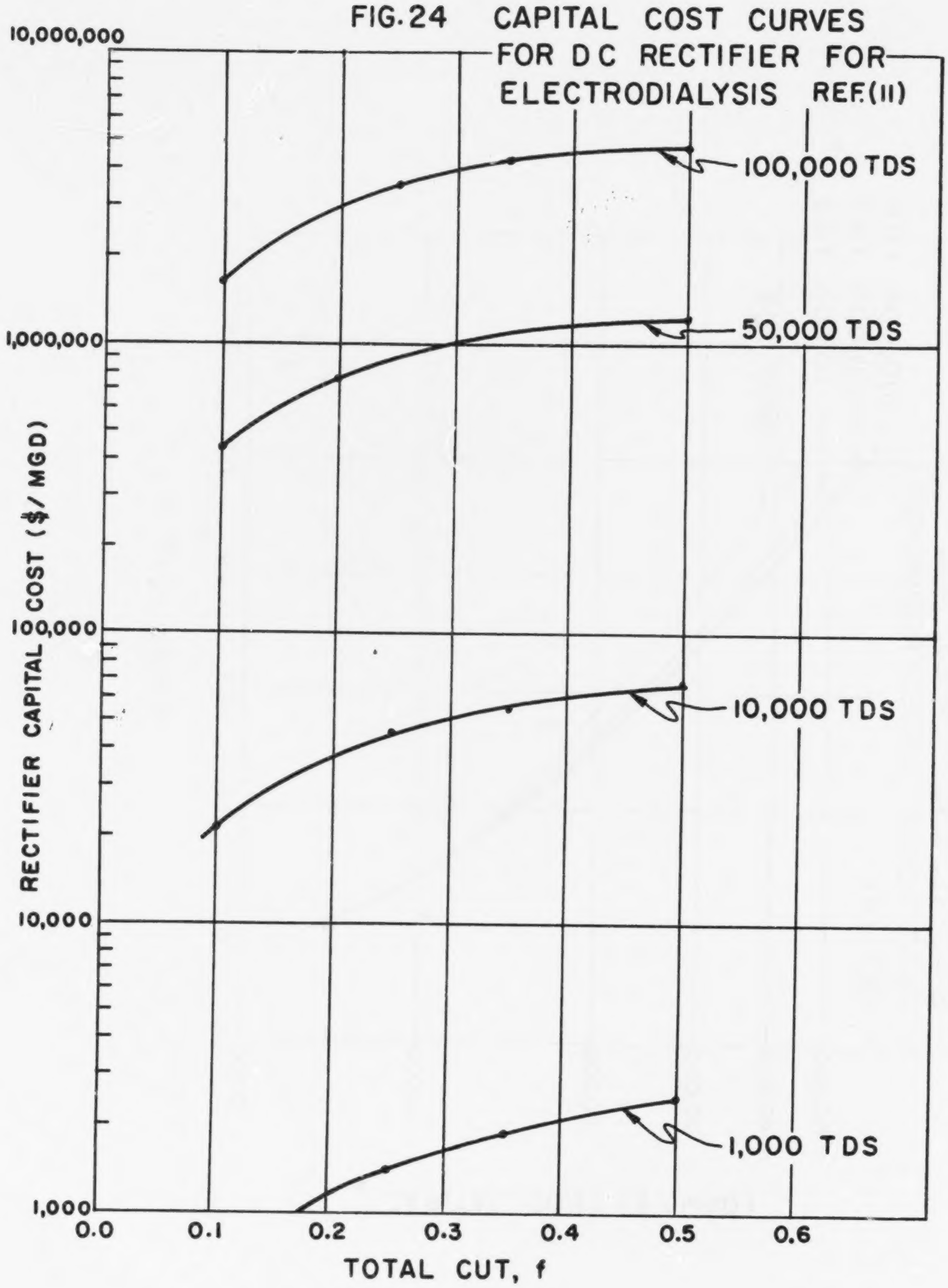


FIGURE 23

CAPITAL COST OF MEMBRANES, SPACERS, END PLATES, AND ELECTRODES (ELECTRODIALYSIS) REF. (11)

FIG. 24 CAPITAL COST CURVES FOR DC RECTIFIER FOR ELECTRODIALYSIS REF.(11)



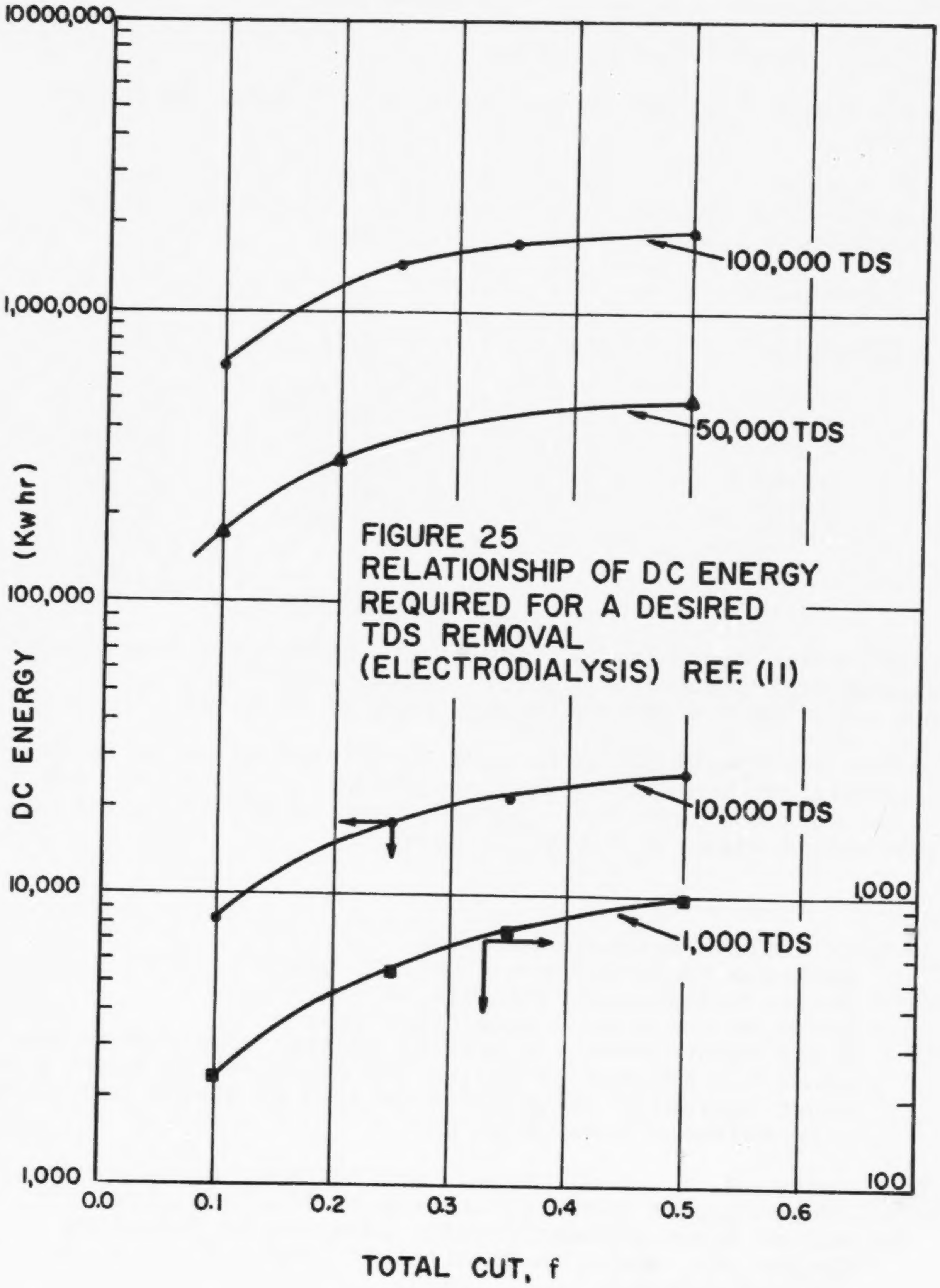


FIGURE 25
RELATIONSHIP OF DC ENERGY REQUIRED FOR A DESIRED TDS REMOVAL (ELECTRODIALYSIS) REF. (11)

From Figure 26: DC Energy Operating Costs @ $0.01/kw-hrs
= 8.40/mgd
Total 1/ = $8.40/day

Costs for 0.5 mgd wastewater at 3000 mg/l total dissolved solids.

From Figure 20, the following units would be required to deliver equal volumes of product water at 500 mg/l total dissolved solids and brine at 10,000 mg/l.

Approximate Feed Concentration	# Units/ mgd	Cost/ Unit	Total Cost
3,000	2.8	58,000	81,000
2,200	2.0	52,000	52,000
1,500	1.4	50,000	35,000
1,000	0.7	47,000	16,000
4,900	1.8	70,000	63,000
6,000	1.0	78,000	78,000
			325,000
			81,000
		Plus 25% for pumps	406,000

These costs were obtained from costs calculated from the fundamental design equations. Similar costs evaluated for other points and those were plotted on Figure 27.

Values for operating costs were calculated as shown in the Appendix and the values also are shown in Figure 27. One value obtained from Ref. (12) is shown to be within the calculated range of operating costs.

1/ Must include maintenance costs:
Membrane replacement = 4 sets/25 years
Spacer replacement = 4 sets/25 years
Anode maintenance - $200/stack year
Other maintenance = 1-1/2% of capital investment/year
Labor = 2 man-hrs./day plus 100 man-hrs. per stack year
Other operating costs would be acid or alkali additions to maintain a suitable pH.

(12) Lacey, R. E., Lang, E. W., and Huffman, E. L., "Economics of Demineralization by Electrodialysis," Saline Water Concession II. Advances in Chemistry Series 38. American Chemical Society, 1155 16th St., N.W., Washington, D.C., 1963.

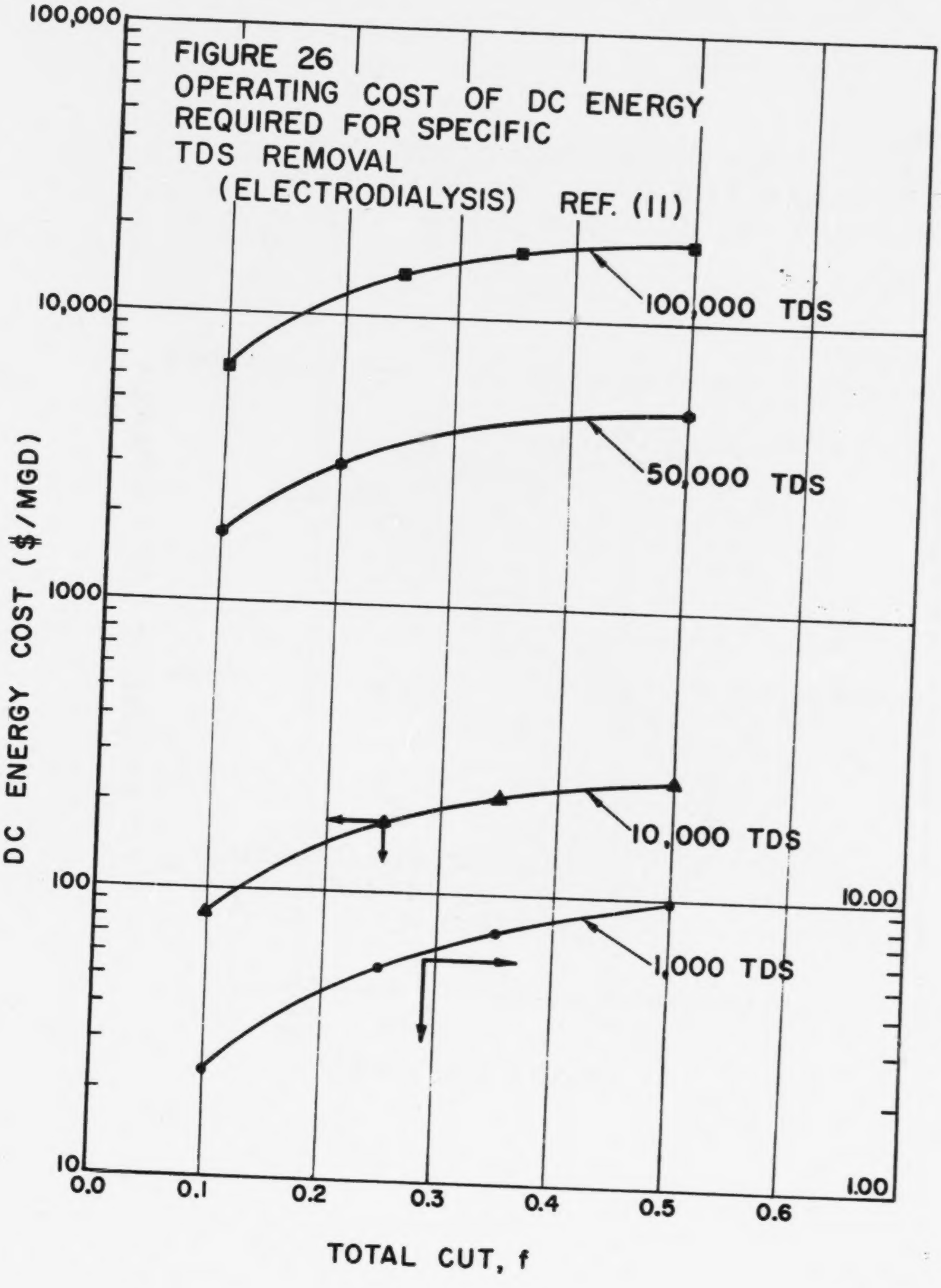
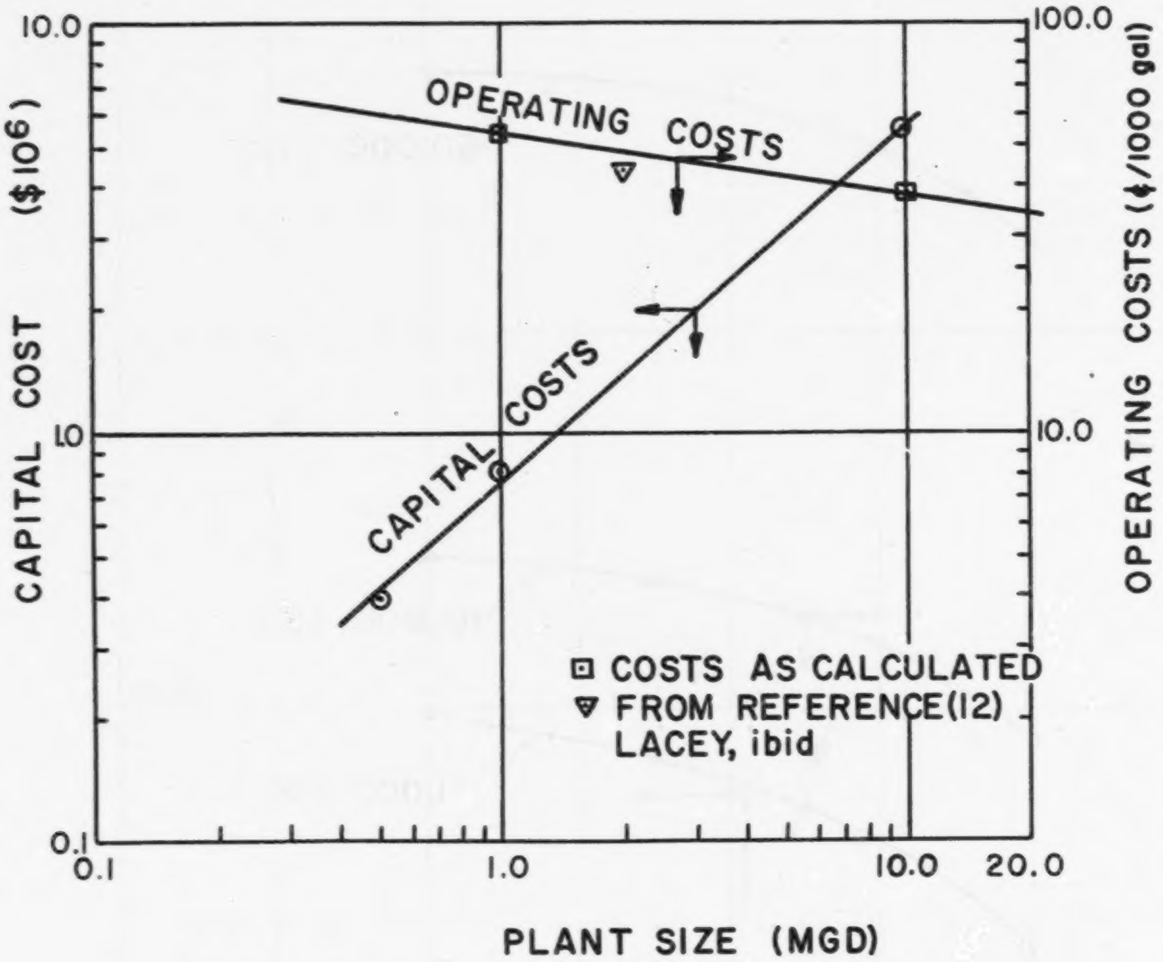


FIGURE 26
OPERATING COST OF DC ENERGY REQUIRED FOR SPECIFIC TDS REMOVAL
(ELECTRODIALYSIS) REF. (11)

FIGURE 27
CAPITAL AND OPERATING COSTS FOR ELECTRODIALYSIS BASED ON FEED FLOW TO PLANT AT 3000 ppm T. D. S.



ION EXCHANGE

The cost of ion exchange plants is dependent on the total volume of waste treated but also to a large extent on the total amount of dissolved solids removed or exchanged since the flow rate through the media remains fairly constant. The regenerant chemical cost will also be in direct proportion to the rate of electrolyte removal. The water used for the wash cycle may for the purpose of treatment, be returned to the filter and recycled and will thus be added to the waste stream. The waste stream will be very concentrated and provide a possibility of recovery of chemicals if such chemicals have any commercial values.

The cost curves in Figure 28 were obtained from the Acid Mine Drainage Report (2) for the Nalco process for an influent TDS of 1500 mg/l. The curve for the Desal Process was obtained from Kunin, et al (13).

The No. 3 curve in Figure 28 was calculated on the basis of the increased capacity required for the increased ion concentration in the waste.

Operating costs for ion exchange were obtained from various sources and pieced together to give a reasonable estimate of the total operating costs. Costs for chemicals used per lb. of TDS removed varies with the initial concentration of the solids in the influent. The curve in Figure 29 was drawn from the following information:

Influent TDS (mg/l)	Chemical Cost per Pound TDS Removed
200	10.2 Ref (14)
354	4.05 Ref (14)
1000	2.0 Ref (15)

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(2) Rice, ibid

(13) Kunin, R., et al "Desal Process-Economic Exchange System for Treating Brackish and Acid Mine Drainage Waters and Waste Effluents," Chemical Engineering Progress Symposium Series No. 90, Vol. 64, AICHE, 1968.

(14) Levendusky, et al "An Innovation in Ion Exchange," Industrial Water Engineering, Vol. 2, 11, Nov., 1965.

(15) Lyons, D., M.S. Thesis, University of Texas at Austin, 1969.

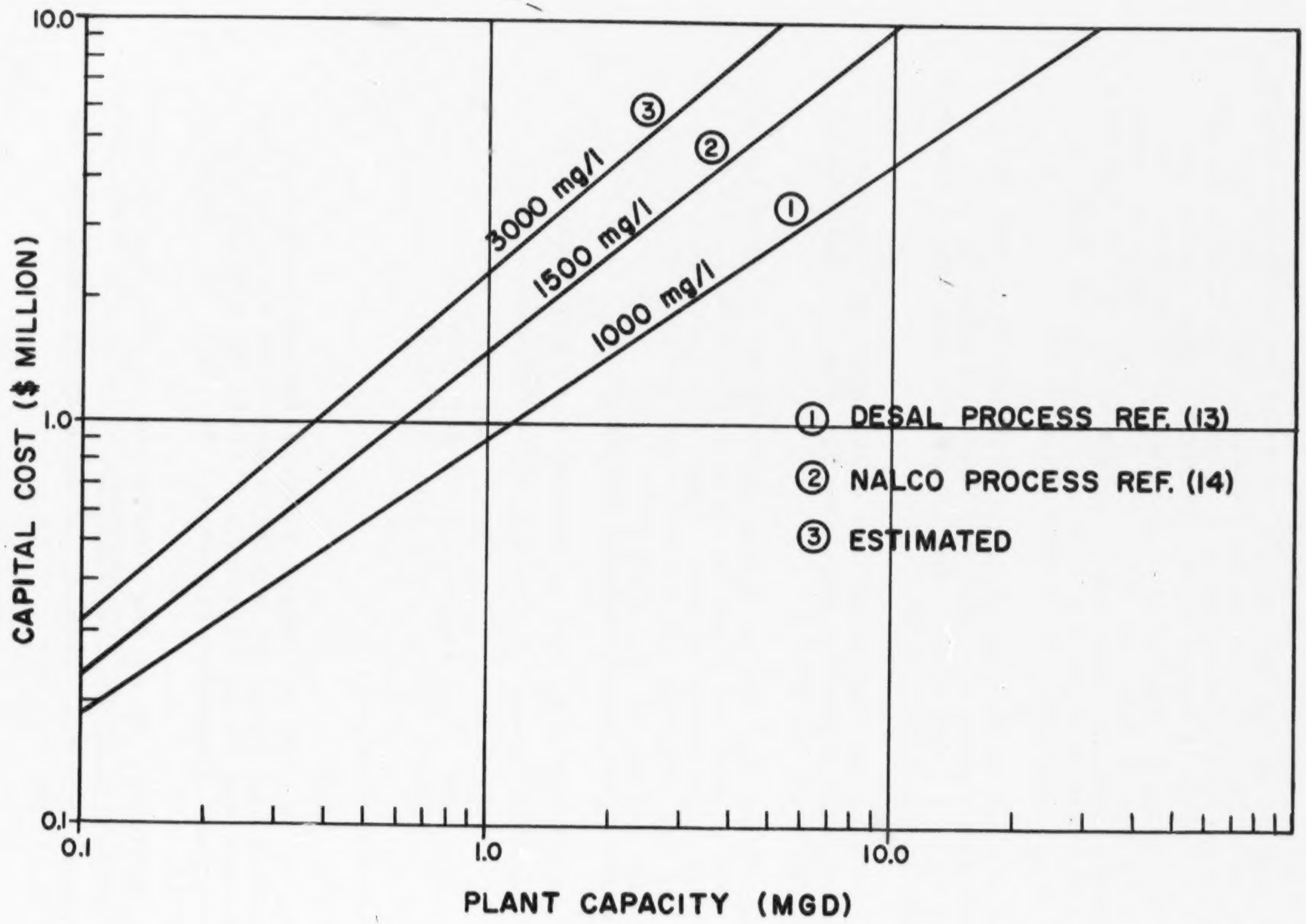

FIGURE 28 CAPITAL COST OF ION EXCHANGE PLANT

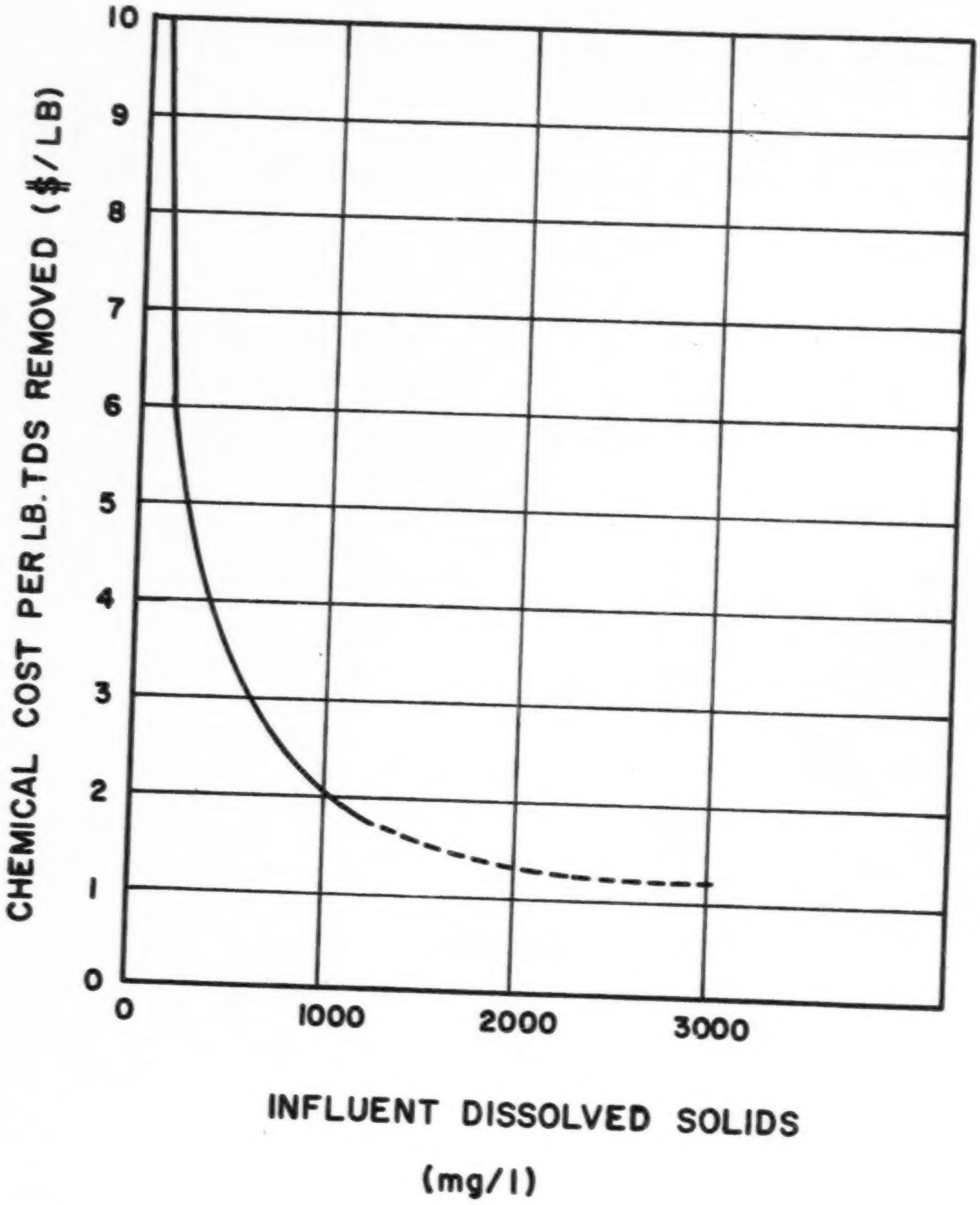

FIG. 29 CHEMICAL COST PER POUND TDS REMOVED BY ION EXCHANGE

The total operating cost for an influent TDS of 3000 mg/l was calculated as follows:

For 0.5 mgd - 2500 mg/l removed for effluent concentration of 500 mg/l

Chemical Costs:
0.001 x 1.5 x 2500 x 8.33 = 31.2¢/1000 gal.

Other Costs:

Labor	1.1
Material	1.4
Chemicals	31.2
Utilities	1.3
	35.0 ¢/1000 gal.

For 1.0 mgd

Labor	0.9
Material	1.2
Chemicals	30.0
Utilities	1.2
	33.3 ¢/1000 gal.

For 10.0 mgd

Labor	0.7
Material	0.9
Chemicals	27.0
Utilities	1.0
	29.6 ¢/1000 gal.

MULTIPLE EFFECT EVAPORATION

The capital and operating costs for multiple effect evaporation was obtained from the report "Cost of Purifying Municipal Wastewater by Distillation." Environmental Health Series, Report No. AWTR-6, U.S. Department of HEW (1963). The costs were based on product water and from the above report, it appears that approximately 10% brine is produced. Few operating costs were available. Additional points were obtained from a report in the 1965 report "Saline Water Conversion Report," U.S. Department of the Interior, Office of Saline Water.

The capital and operating costs are shown in Figure 30.

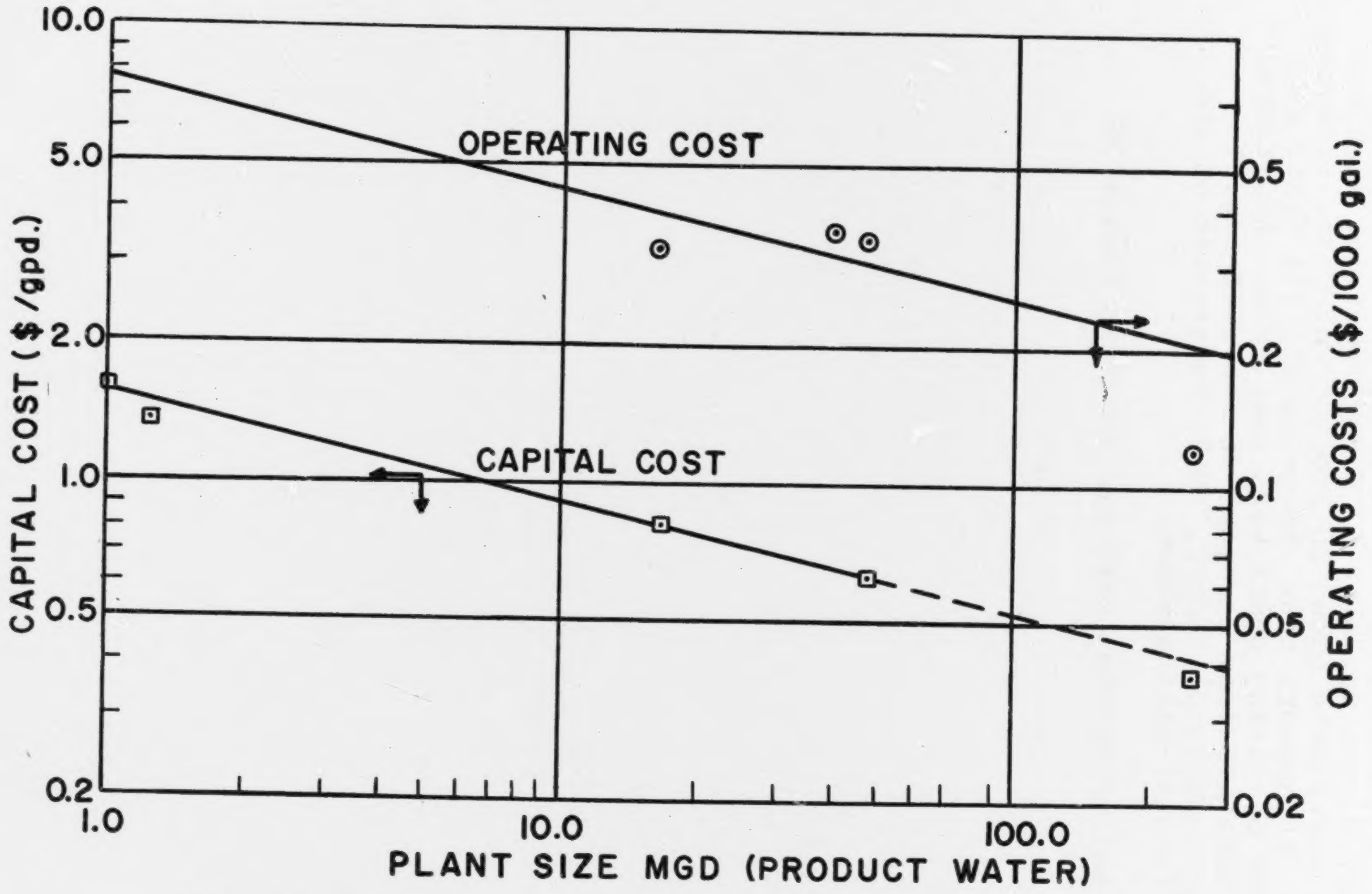

FIGURE 30
CAPITAL AND OPERATING COST FOR MULTIPLE EFFECT EVAPORATION (DISTILLATION)

SOLAR EVAPORATION

Pond evaporation would only be considered in areas where the land is cheap and the net evaporation exceeds the net rainfall by a sufficient margin so as to keep the evaporation ponds within reasonable limits. An example of such a calculation is given below. No areas of pond required are calculated and land value is assumed to be a minimal $100/acre. The costs for construction of the ponds shown in the curve in Figure 34 does not include the cost of land.

Example:
Industry located in Austin, Texas
Discharge -0.1 mgd high solids. T° @ 140°F

METHOD 1 - Average conditions (long term) (Empirical approach)

Determine annual precip. from U.S. Weather Bureau data - 32"

Determine annual lake evaporation from U.S. Weather Bureau = 60"

Net evaporation - 60-32 = 28"/yr or .0735"/day

From Figure 33 enter @ evaporation/day = .074

Read chart @ acres/mgd = 520

Average required = .1 x 520 = 52 acre

(values are 50% occurrence values).

METHOD II - short term conditions - (Rational Approach)

(1) from local weather bureau, or compiled data (17) Determine (95% occurrence value)

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(16) The Nation's Water Resources, USGPO, Washington, D.C., 1968, Part 1.

(17) Evaluated Weather Data for Cooling Equipment, Flow Products Company, Santa Rosa, Calif. (1958)

COX CHART

REF (18) HIMELBLAU, ibid

VAPOR PRESSURE OF WATER VS TEMPERATURE

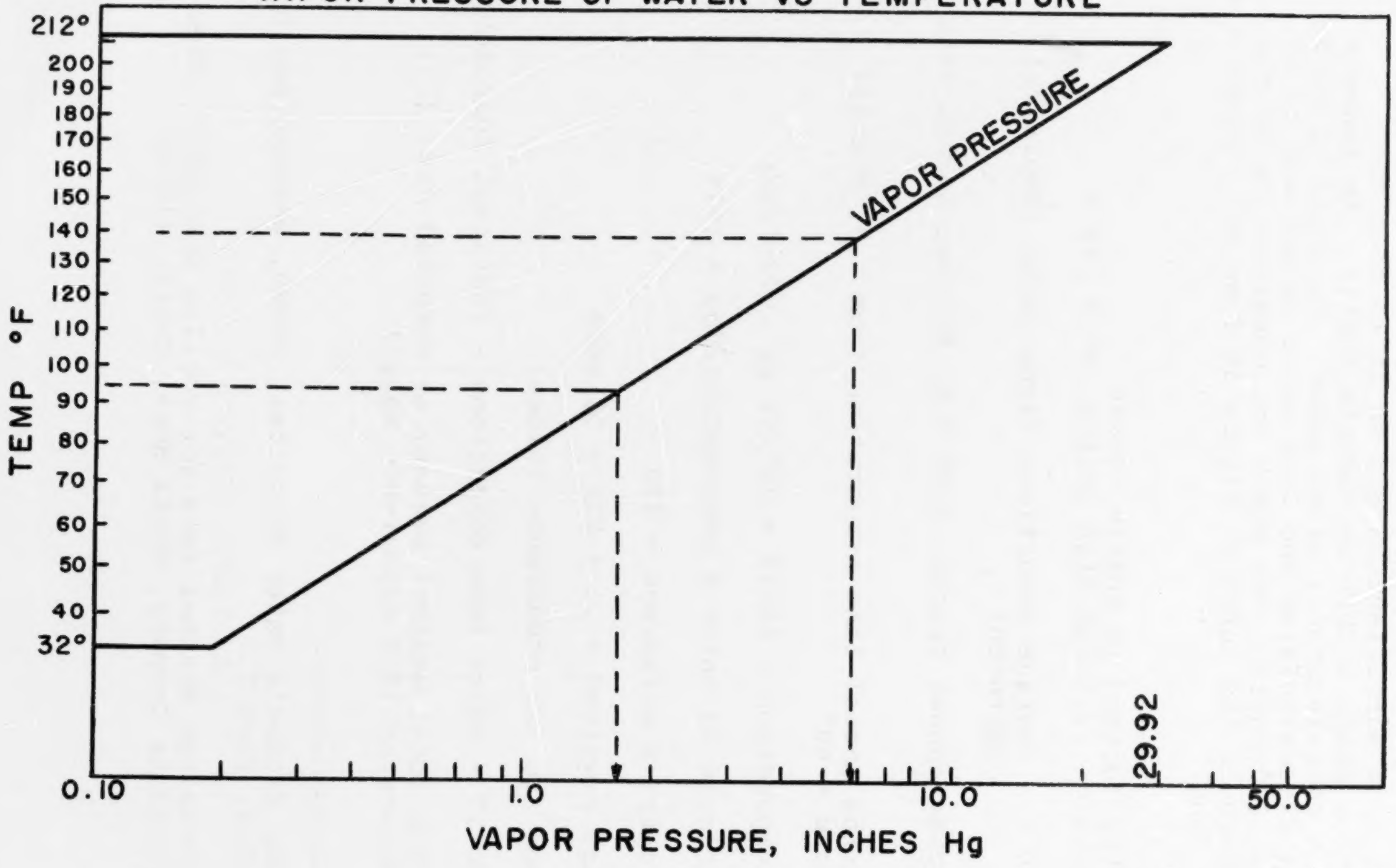

FIGURE 31

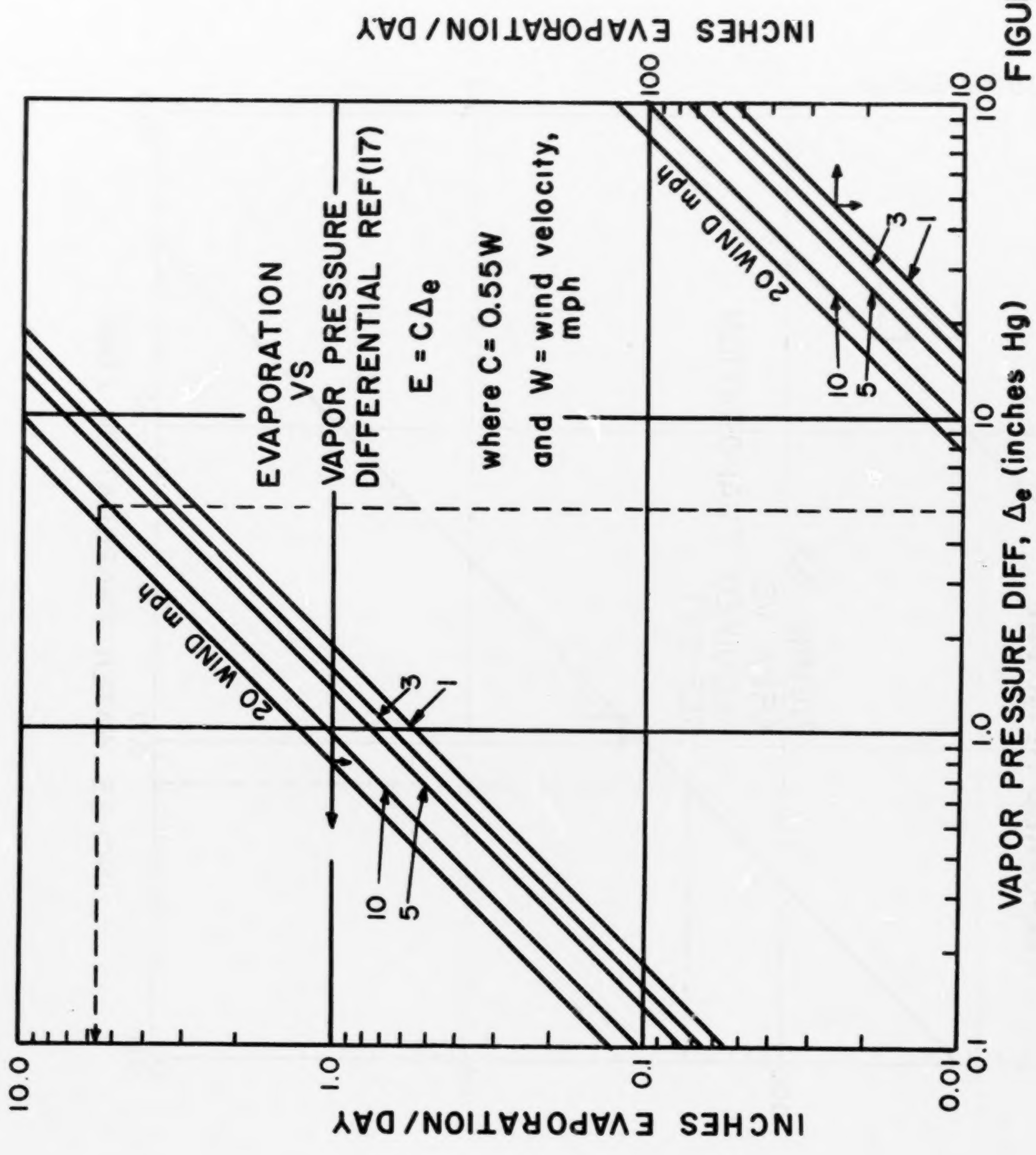
EVAPORATION
VS
VAPOR PRESSURE
DIFFERENTIAL REF(17)
$E = C\Delta_e$
where $C = 0.55W$
and W = wind velocity, mph
20 WIND mph
10
5
3
1
INCHES EVAPORATION/DAY
10.0
1.0
0.1
0.01
0.1
1.0
10
100
VAPOR PRESSURE DIFF, Δ_e (inches Hg)
20 WIND mph
10
5
3
1
INCHES EVAPORATION/DAY
100
10

FIGURE 32

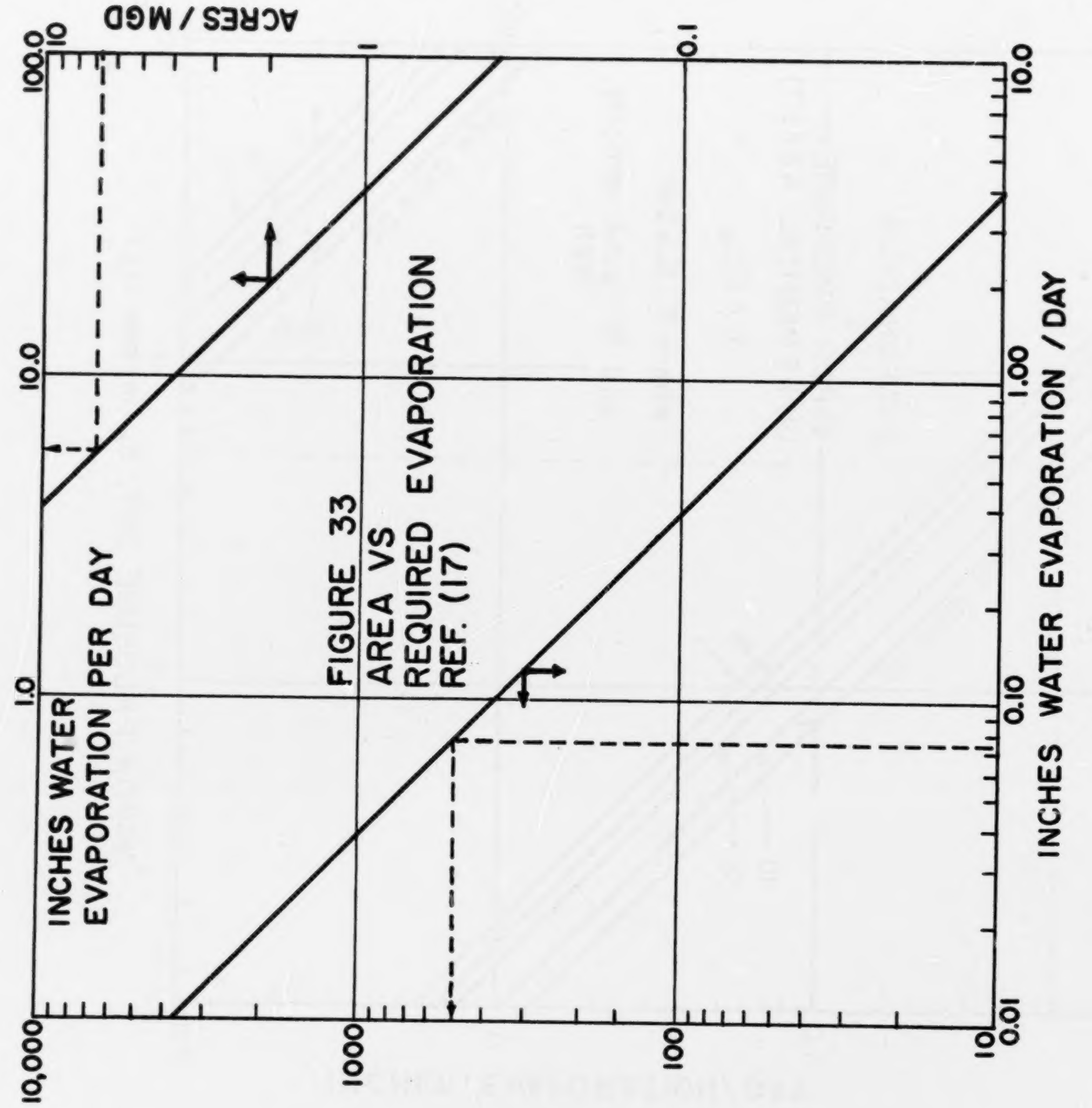

FIGURE 33
AREA VS REQUIRED EVAPORATION
REF. (17)

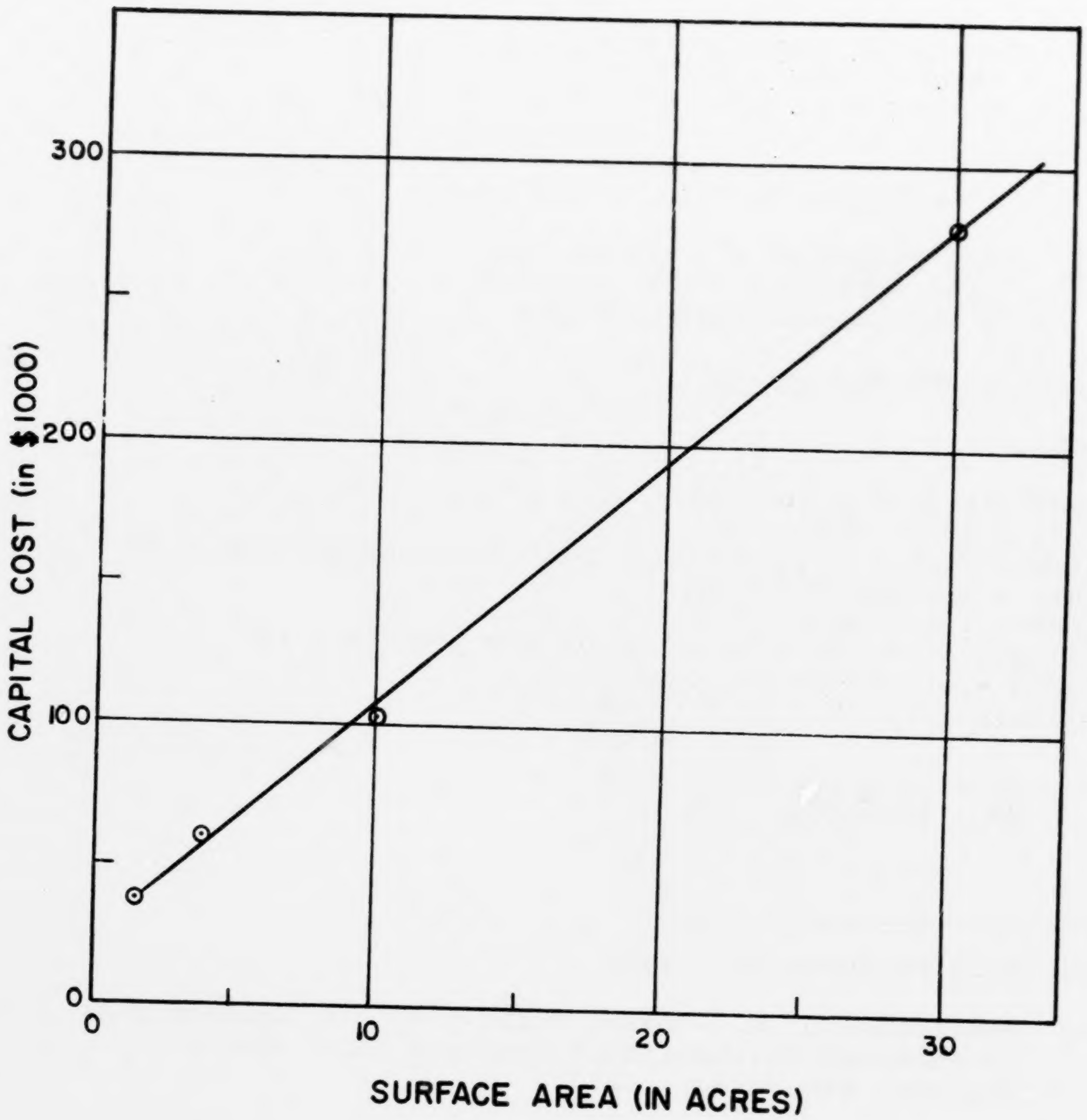

FIGURE 34
CAPITAL COST RELATIONSHIP FOR
LAGOONS REF. (4)

(a) temperature range
wet bulb temp 77° (Figure 19, Ref. 17)
dry bulb temp 95° (Figure 75, Ref. 17)
(b) wind speed - 15 mph (Figure 73, Ref. 17)
(c) relative humidity - 45% (psychrometric chart Figure 69, Ref. 18)

(2) From Figure 31

Determine vapor pressures
water @ 140° = 5.8"
Atmosphere @ 95°F = 1.67 x .45 = .75
$\Delta e = 5.8 - .75 = 5.05$

From Figure 32 Evap. = 5.8"/day

(3) From Figure 33 @ 5.8"/day evap.
read acres/mgd = 6.8 acre/mgd
@ .1 mgd - require .68 acre

Controlled Discharge (19)

Example:

Industry flow @ 200 mgd 308 cfm
Conc @ 1000 TDS = Ci
Stream flow @ 1200 cfs (775 mgd) mean annual flow = SF
Conc @ 100 ppm TDS = Cs
Coefficient variation @
Allowable stream concentration 500 ppm TDS = Ca
Based upon concentration factor -
allowable ratio = $\frac{IF}{SF} = \frac{Ca-Cs}{Ci-Ca}$

or, $\frac{IF}{SF} = \frac{500-100}{1000-500} = \frac{400}{500} = .8$

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(17) Flow Products Co., ibid

(18) Himelblau, D. M., "Basic Principles and Calculations in Chemical Engineering," Prentice Hall, Inc., England, New Jersey, 1967.

(19) Industrial Waste Guide on Thermal Pollution, U.S. Department of the Interior, FWPCA, Pacific Northwest Laboratory, Corvallis, Oregon, September, 1968.

∴ @ any time, industrial flow can be 80% of stream flow or, stream flow must be 125% waste flow

From flow duration curve (USGS)

(1) determine 84% occurrence value and 16% occurrence value
(2) calculate average ratio between these values and 50% occurrence value (Mode); this is Sigma (G) or standard geometric deviation.
(3) Determine coefficient of variation = $\frac{\text{sigma}}{\text{mode}}$

(refer to fraction of flow duration curve)

Example - 50% value - 1200 cfm

85% value - 7100 cfm
16% value - 280 cfm
$= \frac{7100}{1200} = 5.9 \quad \frac{1200}{280} = 4.3$, G Avg = 5.1
plotting geometric normal distribution
low (16%) @ 1200 ÷ 5.1 = 234 high (84%) @ 1200 x 5.1 = 6120

Coef of variation $= \frac{280}{1200} = .233$

or

$\frac{1200}{7100} = .17$

average $= \frac{.23 + .17}{2} = .20$

Entering draft/storage @ ratio industry flow to stream flow

IF/SF = 200/775 = .257

and cost of variability @ .25
Storage factor = .063 MAG
.063 x 775 mgd = 488 MG

Storage required
488 mgd x 365 days = 17,800 MG or 89 days

(4) from flow duration curve, flow of 318 cfm would be exceeded approximately 80% of the time
(5) allowing for dilution factor storage must be minimal by 25% or 17,800 mg x 125% = 22,300 MG

Note: No consideration of rainfall and evaporation has been made; each individual application should consider these factors separately.

Cooling Ponds

Temperature drop through a pond

(1) $To = (Ti-E)e^{-a'} + E$
where
To = outlet temperature °F
Ti = inlet temperature °F
(2) $a' = \frac{KA}{pCpQi}$

where
a' - decay e
K = energy exchange coef. (BTU ft^{-2} day^{-1})
A = pond area (ft^2)
P = water density (62.4# ft^{-3})
Cp = specific heat function (1BTU $lb^{-1}°F^{-1}$)
Qi = influent flow (ft^3 day^{-1})
E = equilibrium

Solving for $K = 157 + (0.26 + B)\ (bW)$

where
W = wind speed in mph
b = experimental evaporation coef.
B = proportionality coefficient

from E(°F)	B($mmHg^{-1}$)
50-60	0.405
60-70	0.555
70-80	0.744
80-90	0.990

Example
Assume b = 12
K = 118
To = 80°F.
E = 769 °F

from eq. (1)
$80 = (93-769)e^{-a'} + 76.9$
$e^{-a'} = 0.193$
$a' = 1.65$
Eq. (2)

$$a' = \frac{118A}{(62.4)(1)(1500)(24)(3600)}$$

$a' = (1.46 \times 10^{-8})\ A = 1.65$
$A = 11.3 \times 10^7\ ft^2$
A = 2590 acres

COOLING TOWERS

Parameter affecting cooling tower costs are (Ref. 20)
(1) Wet bulb temperature - WBT
(2) Approach (CWT-WBT) = A
(3) Range (HWT-CWT) = R

where:
CWT is cooled water temperature
HWT is hot water temperature °F
WBT is web bulb temperature

Example:
An industry is located on a stream having an average dry weather flow of 1 cfm and a dry weather temperature averaging 70°F. Industrial discharge totals 400 gpm at 110°F. Local regulations limit temperature rise to 10°F.

By dilution alone, allowable discharge temperature can be computed by the relationship:

$$TM = \frac{Ti\ Qi + Ts\ Qs}{Qi + Qs} \quad \text{where}$$

or,

$$Ti = \frac{Tm\ (Qi + Qs) - TsQs}{Qi}$$

so, allowable discharge temp.

$$Ti = \frac{80(400 + 450) - 70\ (450)}{400} = 91°$$

and the cooling tower must lower the water temperature from 110°F to 91°F, or a range of approximately 20°. From local data (U.S. Weather Bureau) the average wet bulb temperature is 70° giving an approach of approximately 20°

Entering Figure 35 @ range of 20°, approach of 20°, and WBT of 70° - the relative rating factor of .8.

Using a cost factor of $10.00 per gpm (Ref. 20 + cost index increase)

The capital cost in 1000 x 400 gpm x .8 = $3,200

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(20) Cootner, P. H., Lof, Go. O., "Water Demand for Stream Electric Generation," John Hopkins Press, Baltimore, Maryland, 1965, p. 69.

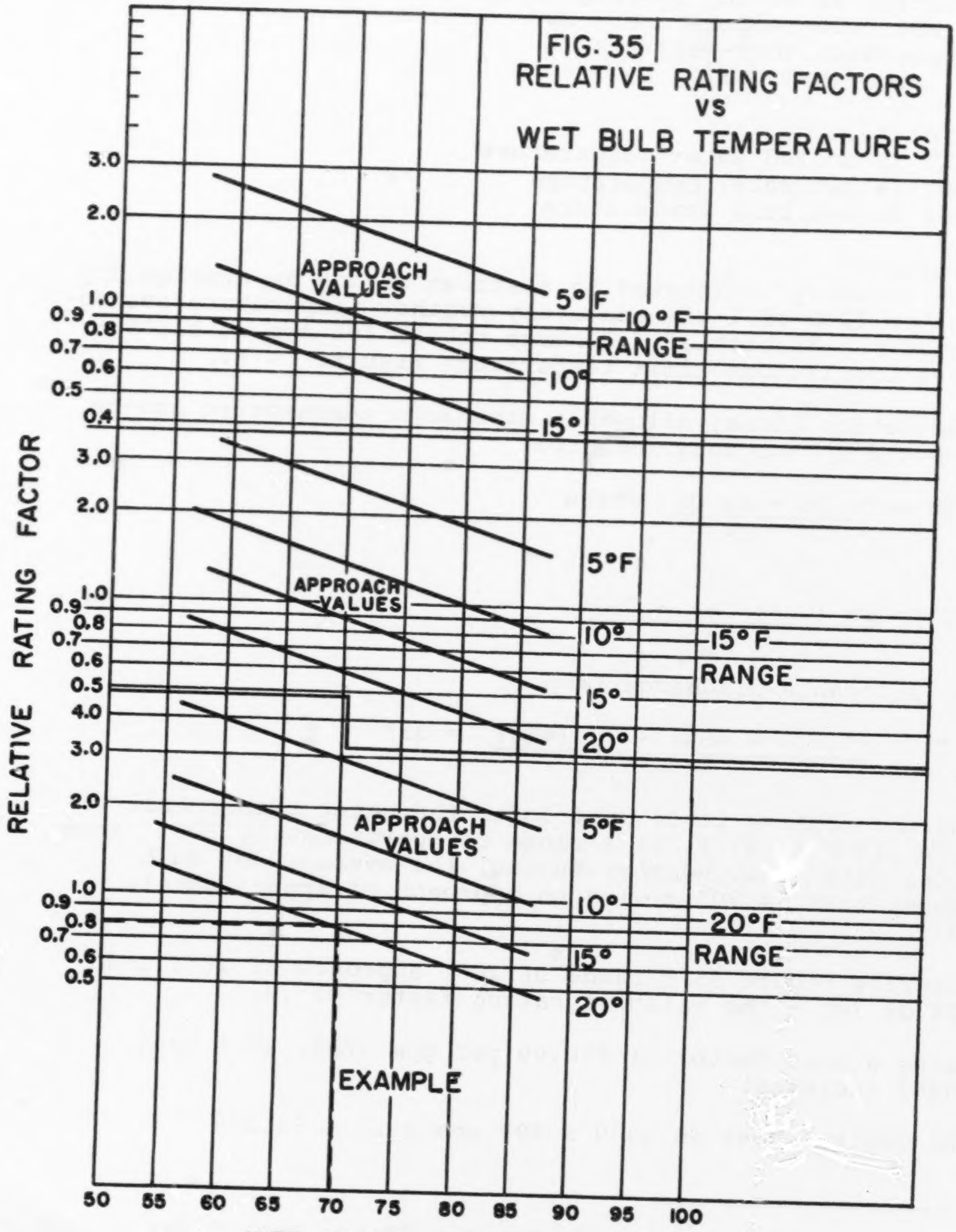

FIG. 35
RELATIVE RATING FACTORS
VS
WET BULB TEMPERATURES

Operating Cost

Cooling tower operating costs
Losses = 0.00112 R
Chemical = $.033\ Y + \frac{17}{C}$
Acquisition = Wa
Power = (0.14K + 0.005A)p

where:
- R = range, °F
- Y = alkalinity, ppm $CaCO_3$
- C = concentration factor
- Wa = cost of water/1000 gal.
- K = Relative factor
- P = Power costs in ¢/KWH
- A = pumping head in

Total operating costs - (¢/1000 gal)
when C=1, assuming Wa=10¢/1000 gal, power @ 1¢/KWH and allowing 0.5 KWH consumption for lifting 1000 gallon 100 feet (approximatey 85% efficiency).

Operating Cost = 0.00112 R (.033 Y + 17) + 10 + (.14K + .005A)

Example using graph in Figure 36:

Cooling tower operating under @ 20° range with a relative rating factor of 1.0, alkalinity of 1000, and assuming 100 foot operating head, cost/1000 gal= 2¢, assume 100,000 gpd flow, then operating cost - 2¢ x 100 = $200/day.

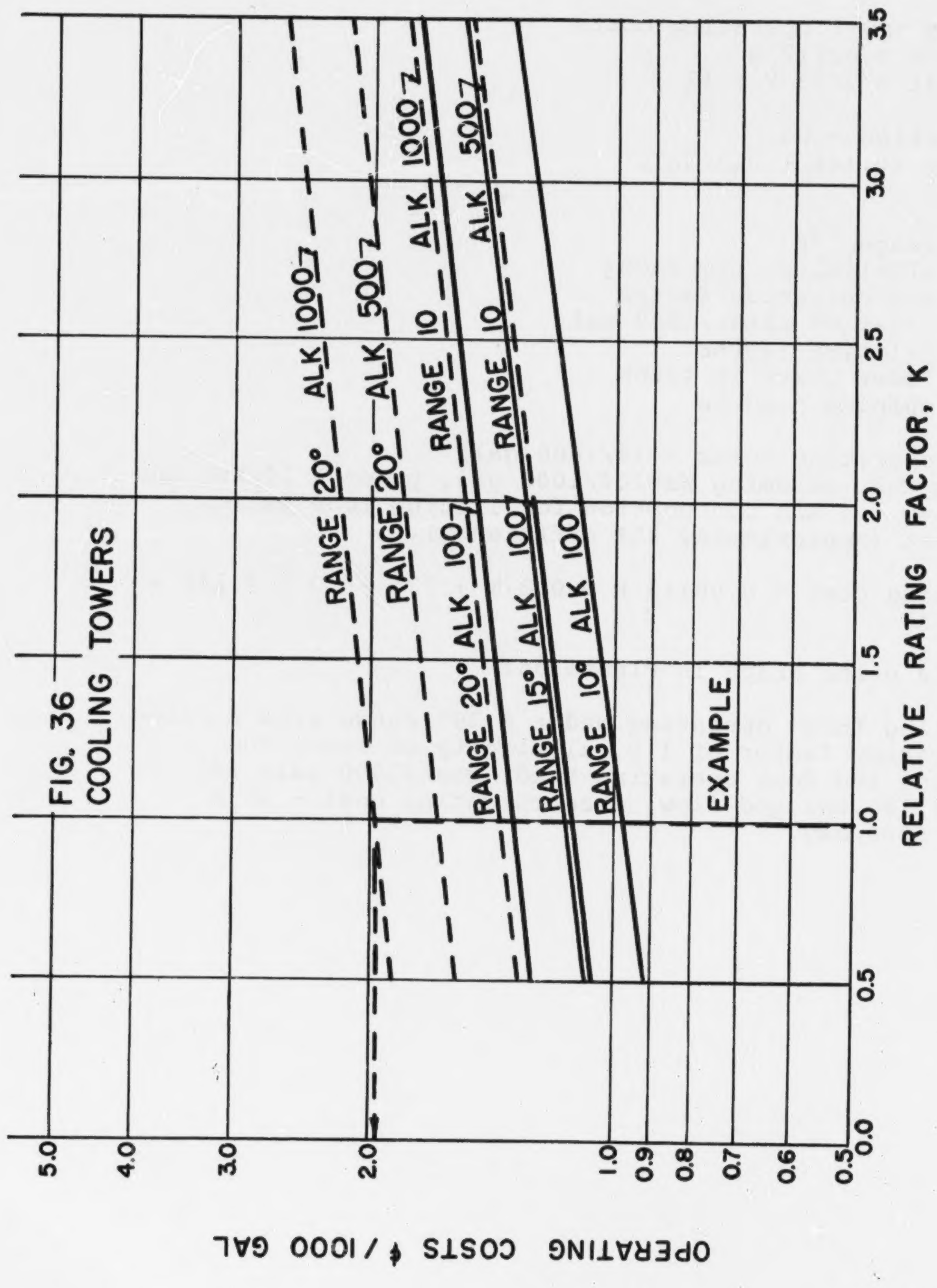

FIG. 36
COOLING TOWERS

APPENDIX D

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27 *Abstract*

This report presents a description of the inorganic chemical industry and the costs that the industry would incur in attaining various levels of pollution abatement over the five-year period through 1974. For the study purposes, the inorganic chemical industry has been defined as including establishments producing alkalies and chlorine, industrial gases, inorganic pigments, paints and allied products, fertilizers (excluding ammonia and urea), inorganic insecticides and herbicides, explosives, and other major industrial inorganic chemicals. The report presents in considerable detail the description of the various production processes, the waste treatment methods practiced, and the possible impact that changes in processes might have on the volume and character of the wastes produced.

Projections have been based upon the chemical industry data in the 1963 and 1967 Census of Manufacturers, the 1967 Manufacturing Chemists Association survey, and the 1968 FWPCA study of the organic chemicals industry. Costs of treatment are estimated by year for the levels of treatment corresponding to 27% and 100% removal of contaminants. Data from 59 inorganic chemical plants were obtained as primary input to the study.

Abstractor Dr. Henry C. Bramer

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